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Evaluation of the impact of QREN SI I&DT instrument on Portuguese firms – a behavioural case-study analysis

by

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Biographic Note

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Abstract

Public support to business research and development (R&D) is considered essential to overcome market limitations and reduce the cost of firm's investment in R&D activities. Public R&D funding is one of the innovation policy instruments used to stimulate business R&D and promote innovation. The Incentive System for Research and Technology Development in firms (SI I&DT) implemented in Portugal within the National Strategy Reference Framework (QREN), which ran from 2007 to 2013, is one example of innovation policy instruments aimed at firms. The evaluation of the impact of innovation policy instruments is relevant to the review process of innovation policies, and an indispensable to evaluate the effectiveness of allocated investments and the return generated for the national economy. This dissertation presents a contribution towards the evaluation of SI I&DT instrument, performed through an analysis of project approval and execution data, and an exploratory case-study analysis into the additionalities induced by the incentive at firm level, with particular emphasis on behavioural additionality. The results show that overall the SI I&DT had a positive contribution towards improving the national business R&D intensity, and promoting collaborations between firms and public research organizations. The case-study analysis demonstrated that the SI I&DT incentive induced behavioural changes within the beneficiary firms, at different strategic and operational levels. It also emerged from these case-studies that behavioural impacts can promote future R&D activities through acquired knowledge application, sustained established collaborations and improved innovation management skills. These results confirm that public funding policies can induce a wide scope of additionalities within firms with persistent character, which can improve their ability to conduct R&D and potentiate higher innovation intensity. This dissertation provided a valuable insight and contribution into the characterization of behavioural additionality impacts of R&D incentives in the Portuguese context, which is still unexplored.

Resumo

O apoio público à investigação e desenvolvimento (I&D) de cariz empresarial é considerado essencial para ultrapassar limitações existentes no mercado que constituem barreiras ao envolvimento das empresas nestas atividades. Um dos instrumentos de política de inovação para estimular as atividades de I&D empresariais e promover a inovação neste meio são incentivos públicos. O Sistema de Incentivos à Investigação e Desenvolvimento Tecnológico (SI I&DT) enquadrado no Quadro de Referência Estratégia Nacional (QREN) que decorreu entre 2007-2013 é um dos exemplos deste instrumento da política de inovação nacional dirigido a empresas. A avaliação do impacto destes instrumentos de política pública para promoção da I&D empresarial é relevante para o processo de revisão destas políticas, sendo um processo indispensável para avaliar a eficácia dos investimentos atribuídos e o retorno gerado para a economia nacional. A presente dissertação apresenta uma contribuição para a avaliação do instrumento SI I&DT, que foi desenvolvida através da análise de dados relativos à aprovação e execução destes incentivos, e complementada por uma análise exploratória de estudos de caso da atonalidade induzida pelo incentivo entre empresas beneficiárias, com particular enfâse na vertente de comportamental. Os resultados demonstram que no global o SI I&DT teve uma contribuição positiva para o aumento da intensidade do esforço de I&D empresarial, assim como na promoção de colaborações entre empresas e organismos de investigação públicos. A avaliação dos estudos de caso demonstrou que o SI I&DT induziu mudanças de caráter comportamental ao nível operacional e estratégico nas empresas beneficiárias. Estes estudos de casos também evidenciaram que esta adicionalidade comportamental pode potenciar atividades de I&D futuros, pela aplicação de novos conhecimentos adquiridos, colaborações estáveis estabelecidas e competências de gestão de inovação melhoradas. Estes resultados confirmam que políticas de financiamento público podem induzir um extenso conjunto de adicionalidades com caráter persistente, que pode contribuir positivamente para forma como as empresas conduzem processos de inovação. Esta dissertação contribuiu para a caracterização da adicionalidade comportamental de incentivos à I&D empresarial, que ainda é um tema inexplorado no contexto nacional.

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List of Abbreviations

AdI	National Innovation Agency
BA	Behavioural Additionality
BERD	Business Expenditure in R&D
CEO	Chief Executive Officer
EU	European Union
EU28	European Union with 28 member countries
FEDER	European Regional Development Fund
FSE	European Social Fund
GDP	Gross Domestic Product
GERD	Gross Expenditure in R&D
HR	Human resources
IAPMEI	National Agency for Innovation and Competitiveness
IPCTN	National Scientific and Technologic Potential Survey
NIS	National Innovation System
PM	Project Manager
PO	Regional Operational Programmes
POFC	Competitive Factors Operational Programmes
PRO	Public Research Organization
QREN	National Strategic Reference Framework 2007-2013
R&D	Research and Development
SAESCTN	Science and Technology Organizations Support System
SI I&DT	Incentive System for Research and Technology Development
SME	Small and medium-sized enterprise
TRL	Technology Readiness Level

1. Introduction

Public support for business research and development (R&D) is considered essential to overcome existing market limitations which prevent firms to engage in these activities. Among these limitations are low appropriability of R&D results, highly uncertain returns and capital market limitations. Public R&D funding is one of the innovation policy instruments used to stimulate business R&D and promote innovation.

The Incentive System for Research and Technology Development in firms (SI I&DT) implemented in Portugal within the National Strategy Reference Framework (QREN[1]), which ran from 2007 to 2013, is one example of innovation policy instruments aimed at firms. This was considered an important strategy to intensify the R&D performance of Portuguese firms and increase their innovative potential, which is below the EU average. QREN SI I&DT is considered to be the first R&D funding programme designed to fund national business R&D, which had an unprecedented volume of incentives awarded to a wide range of beneficiary firms.

The evaluation of R&D public intervention is relevant to the review process of innovation policies, and a crucial process to evaluate the effectiveness of allocated investments and the return generated for the national economy. Following the conclusion of the QREN programme in 2015, it is pertinent to perform an evaluation of the results the SI I&DT instrument produced among the beneficiary firms and business R&D overall. This evaluation is generally based on the additionality of the incentive, that traditionally focuses on input and output impacts of the awarded funding, where the increased R&D expenditure by the firm and economic impacts attributed to the project are considered, respectively.

A more recent form of additionality – behavioural - has been proposed to explain the changes occurring within the firm that can be attribute to the R&D incentive intervention. This concept allows to investigate whether firms become more capable to perform R&D activities as a result of their R&D funding experience, and if the changes introduced by this process become permanent (Falk, 2007). This is therefore and important perspective

[1] QREN (Quadro de Referência Estratégica Nacional) was the "National Strategic Reference Framework which constitutes the framing for the application of the Community's policy for economic and social cohesion in Portugal for the 2007-2013 period" (QREN, 2007).

to be included in the assessment of the impact of public business R&D incentives, and has been regarded by some authors as possibly the most long-term impact of the R&D public policy (Davenport *et al.*, 1998).

The present investigation aims to contribute towards the evaluation of the impact the QREN SI I&DT instrument had overall at promoting business R&D at national level, and also at firm level, through an additionality case-study analysis.

The contribution of this dissertation is twofold. Firstly, it provides an overview of the SI I&DT execution and overall impact in comparison with the policy set objectives, considering the national business R&D context. Secondly, and most relevantly, it presents a behavioural analysis of SI I&DT incentives attributed to selected beneficiary firms. This was performed through a case-study analysis performed to firms with different dimension and technology intensity. To the best of our knowledge, this is a unique contribution since behavioural additionality studies are limited in the literature, particularly in the Portuguese context.

The outline of this dissertation is as follows. Chapter 2 presents a literature review on the fundamentals of business R&D public intervention, the impact of public incentives and behavioural additionality. In chapter 3 a characterization of the Portuguese R&D performance is presented, contextualizing the business R&D evolution since 2000 at European, national and sectorial levels. Chapter 4 describes the methodology applied to perform this research, along with the selected case-study firms' description. Chapter 5 contextualizes the QREN framework and the SI I&DT instrument and presents approval and execution data of projects conducted under this instrument, which is complemented with considerations regarding this analysis. Chapter 6 presents the results and discussion of the case-study analysis performed to SI I&DT beneficiary firms. The conclusions of this dissertation are summarized in Chapter 7.

2. Literature Review

2.1 Fundamentals of business R&D public intervention

It is recognized that technological progress, derived from Research and Development (R&D) activities, has a positive impact on the growth and productivity of a country's economy (Romer, 1986; Rosenberg, 1974):

*"In the long run, the world's growth rate is driven by discoveries in the technologically leading economies" (*Barro and Sala-i-Martin, 1997:23).

The success of each country's economic development depends on its capacity to generate and absorb new knowledge, either by own R&D or catching-up activities, that can in turn be translated into innovations – this capacity is generally articulated through a framework set by the National Innovation systems (NIS) (Metcalfe and Ramlogan, 2008). The NIS are made of institutions, such as government, academia and private firms, whose interaction and coordinated activities promote the generation of new knowledge and innovations that contribute to economic development. The interactions between these three institutions have evolved from being contained and independent to collaborative and role-changing, as described by the *Triple-Helix* model proposed by Etzkowitz and Leydesdorff (2000). In this context, firms hold the singular role of transforming inventions into innovations, that is, to create economic value from new and applied knowledge (Fagerberg, 2004). Firms are so considered the most important organization within the NIS (Edquist, 2004).

According to the Frascati Manual (OCDE, 2002:30), Research and Development (R&D) activities "*comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications*". These activities can be further categorised into three types (OECD, 2002):

- **Basic research**, R&D directed to acquire new knowledge generally with a fundamental nature and deep understanding of the phenomena and observations, which is carried out without any intended application;

- **Applied research**, R&D directed to investigate new knowledge with a practical objective or application in sight;
- **Experimental research**, systematic work based on the acquired new knowledge that is applied to create new or improved processes or products.

Basic and applied research can be carried out by academia (scientific institutions), while applied research and experimental research are performed by business R&D. Firms engage in the innovation processes in different ways and with varying levels of intensity, depending on the intrinsic characteristics of each industrial sector. These innovative pathways can be classified according to the sources of new technology, requirements of users and possibilities for appropriation (Pavitt, 1984). For example, the pharmaceutical industry typically engages in intense in-house R&D activities and relies on patenting for product protection, while the textile industry generally relies on equipment suppliers to implement new technologies and uses trademarks and marketing as means of innovation appropriation. According to the Pavitt classification of technological patterns, the pharmaceutical industry can be categorised as "Science Based", while the textile industry categorised as "Supplier dominated" (Pavitt, 1984). This classification system highlights the different patterns of innovation that can be found across industrial sectors, and the different levels of R&D intensity that are characteristic of each sector.

From a business point of view, the motivation to carry out R&D is to exploit profit opportunities, that arise from the implementation of improved processes and /or introduction of novel products in the market ahead of its competitors (Nelson, 1959). As many contributions have shown, business R&D has a relevant impact on growth and productivity of firms and countries (Bravo-Ortega and Marin, 2011). However, due to market limitations, the desired business R&D is sub-optimal. The reason is that projects that could benefit society, i.e. have high social return, do not compensate the private costs to develop these innovations, due to positive externalities effects (Arrow, 1962; Nelson, 1959). Without any external incentives, the innovations would be below the desirable social level (Almus and Czarnitzki, 2003). Public intervention is therefore a necessary instrument to overcome these market limitations and reduce the cost of firms' investment in R&D activities (Czarnitzki and Toole, 2007; Guellec and De La Potterie, 2003).

According to several authors, the aforementioned market limitations are typically twofold as follows (Arrow, 1962; Hall, 2002; Nelson, 1959):

- **Low appropriability**: This limitation relies on the fact that new knowledge is by nature non-rivalrous and not completely excludable, thus can be appropriated by other parties at much lower cost to generate their own R&D (Becker, 2015). This low appropriability reduces R&D returns for the innovation promoter, and determines that the private rate of return is lower than the social return. This gap is even wider in basic research, therefore requiring a stronger government intervention. Intellectual property protection mechanisms can minimise this limitation, however, as stated by Arrow (1962), these mechanisms are not enough to protect the access to information and only offer a partial barrier to knowledge diffusion. Even patents cannot protect knowledge spill-overs and may be used to further develop other innovations, with lower investment costs. In light of this constraint, public funding can provide financial incentive to mitigate these losses and thus encourage business R&D. If govern policy is effective, public funding should encourage and promote further business R&D (Guellec and De La Potterie, 2003).
- **Capital Market Imperfections**: This limitation is associated with the fact that firms without financial assets to support their R&D activities may not carry out these activities due to high cost of external capital (Silva and Silva, 2016). The level of risk and uncertainty associated with R&D makes these activities difficult to finance through the banking system, especially in the case of SMEs which typically hold low levels of collateral assets (Czarnitzki and Toole, 2007). Therefore, external intervention is needed to provide financial support to promote these activities. Additionally, due to the unpredictability associated with R&D outcomes, some firms may consider engaging in other safer investments rather than invest in R&D or product innovations, even if investment returns could be higher in the latter case. Public incentives can be applied to minimise and overcome uncertainty associated to R&D investments.

Public R&D policies are composed of a set instruments, but these can be generically organized into three categories: support towards higher education programmes and basic

research in academia, direct subsidies and tax incentives for private sector, and other initiatives across different institutions promoting R&D cooperation (Becker, 2015). The public policies instruments directed towards business R&D, mainly subsidies, can be further differentiated to benefit certain business sectors that are considered strategic for technological development or targeting different regional levels towards development cohesion.

2.2 Impact of public incentives

As stated by Porter (1990:73) "*A nations' competitiveness depends on the capacity of its industry to innovate and upgrade*". For this reason, promoting R&D activity has become a central topic of any country's political agenda to maximize growth. At European level, these efforts are currently consolidated in the Europe 2020 Strategy, which defines targets to improve the conditions for innovation and R&D development, where a R&D investment target of 3% of GDP by 2020 was set, with two thirds coming from the private sector (Eurostat, 2017). At national level, this R&D intensity goal was set to 2.7% of GDP by 2020 (Varum and Viegas, 2015). Although there is an alignment between the national and EU 2020 agendas' to increase the R&D efforts, the latest Portuguese R&D performing figures (BERD of 1,27% of GDP in 2016) clearly show that the national R&D intensity is still low and that this target might be too ambitious to be achieved (Pordata, 2017a). Public incentives to business R&D are a relevant part of the framework set-up to address this challenge and close the gap in the current R&D intensity deficit.

From a policy improvement point of view, and also given the current financial setting, it is important to thoroughly evaluate the impact of these instruments on business R&D, and analyse whether this public funding is being targeted correctly and applied effectively (Becker, 2015). Policy evaluation has evolved from focusing on the direct effects that firms achieve through incentives, to a more thorough evaluation of the overall effects the incentive provided – considered the additionality effect of the incentive (Barbieri *et al.*, 2012). As described by Georghiou (2002:58) the additionality concept "*involves comparison with the null hypothesis or counterfactual – what would have happened if no intervention had taken place*".

Additionality is generally further categorised into Input additionality and Output additionality (Georghiou, 2004). Output additionality addresses the outcomes that would not have been achieved if the incentive was not conceded in the first place. This can include evaluation of direct outputs of the firms' innovation process, such as novel products launched or patents, or indirect outputs, such as market share and profitability (Clarysse *et al.*, 2004; Clarysse *et al.*, 2009).

Input additionally if by far the most studied type to evaluate the R&D funding effectiveness and is considered the easiest to verify (Barbieri *et al.*, 2012; Varum and Viegas, 2015). This type of additionality derives from one of the main policy objectives to increase R&D intensity, and evaluates whether the beneficiary firm spends more funds in R&D than it would have if the incentive was not conceded, i.e., if for each Euro provided by the subsidy the firm spends additional private funds on R&D (Georghiou, 2002; IDEA Consult, 2009). The study of this additionality has gathered much interest in the literature, evaluating whether these incentives stimulate private R&D investment or in turn are a substitute of these investments – an effect generally referred as the crowding-out effect.

David *et al.*, (2000), conducted and extensive survey of econometric studies performed over a period of 35 years to investigated the occurrence of the crowding-out effect. The authors concluded the results were ambivalent, but were able to identify this crowding-out effect in a third of the selected studies. Similar ambiguous relation was found by Garcia-Quevedo (2004) in a meta-analysis of data gathered from previous review studies, although a slight tendency for crowding-out effect was found. Both these authors claim that the different approaches, levels of aggregation and geographical distribution of the available studies compromises the analysis and comparisons performed. The application of improved econometric techniques combined with a better focus on data aggregation levels, provided a more consistent and unbiased analysis in recent studies. At a country-level, recent studies have identified the prevalence of additionality effects and refute the hypothesis of crowding-out, evidencing that incentives are generally effectively used to increase business research and innovation efforts. Such studies have been performed across a range of European countries using large samples of firms (over 1000), in countries including Spain, Eastern Germany, Italy, Belgium and Norway, among others (Gonzalez and Pazo, 2008; Almus and Czarnitzki, 2003; Carboni, 2011; Aerts and

Czarnitzki, 2004; Clausen, 2009). In addition, studies considering firm size present some evidence that SMEs utilize these public incentives more effectively than larger firms, and also that low-tech firms benefit more of this public finding than high-tech firms, that already have a high R&D intensity (Gonzalez *et al.*, 2005; Gonzalez and Pazo, 2008).

In light of this evidence, there seems to be a growing consensus that public incentives are being effectively applied to increase business R&D (Becker, *et al.*, 2015; Barbieri *et al.*, 2012). Still, some authors argue that a more extensive and thorough analysis is warranted to evaluate the complexity of policy intervention and its impacts on the firms' conduct (Barbieri *et al.*, 2012). A third type of additionally – behavioural - has been proposed to complement this analysis and study the impacts these incentives can have on the organization, beyond the ones identified through input and output analysis (Clarysse et al, 2009).

2.3 Behaviour Additionality of R&D

The behavioural additionality (BA) concept was firstly introduced by Buisseret *et al.* (1995), who stated that "*companies and institutions undertaking publicly sponsored projects are rarely left unchanged by the experience*". This additionality can generally be defined as the changes that occur in the firm behaviour as a result of public incentive intervention, and that otherwise would not have taken place (Cerulli *et al.*, 2016; Georghiou, 2004). This concept emerged from the acknowledgment that the traditional additionality analysis of public incentives is limited, in a sense that it focuses on economic impacts and other positive impacts derived from public intervention, such as novel capabilities or competences developed, are overlooked. This concept allows to investigate whether firms become more capable to perform R&D activities as a result of their R&D funding experience, and if the changes introduced by this process become permanent (Falk, 2007). This is therefore and important perspective to be included in the assessment of the impact of public business R&D incentives, and has been regarded by some authors as possibly the most long-term impact of the R&D public policy (Davenport *et al.*, 1998).

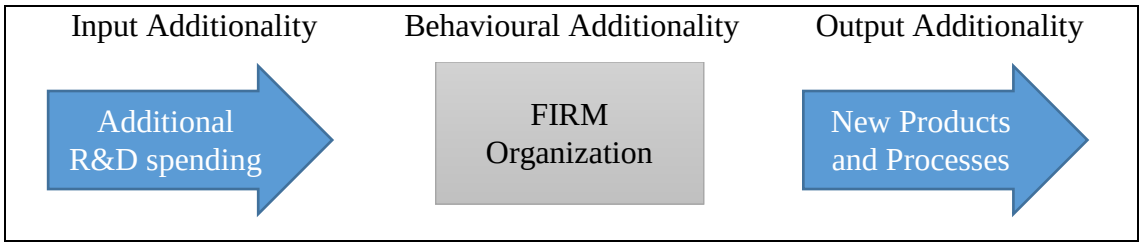
The theoretical background of BA is supported by two views – the Resource Based view and Value Innovation approach (Georghiou and Clarysse, 2006).

The Resource Based theory explores the connection between the firm's performance and the resources it detains (Barney, 1991; Teece *et al.*, 1997). According to this theory, competitive advantages can emerge if the firm possesses a pool of resources with the following characteristics: valuable, rare, non-imitable and non-substitutable (Barney, 1991). These resources include a wide range of assets, which can be classified as physical capital resources (infra-structure, technologies, process, etc), human capital resources (knowledge, training, experience, networks, etc) and organizational capital resources (formal reporting, planning, controlling, etc; Barney, 1991). Emphasis is put at management level to recognise the potential of these internal resources and define strategies to achieve sustained competitive advantages. The importance of these management skills is also highlighted in the Dynamic Capabilities framework proposed by Teece and Pisano (1994). Where the term "Dynamic" denotes the ongoing changes occurring in the external market environment, and the term "Capabilities" relates to the strategic management capacity to adapt, integrate and reorganize internal resources and competences in order to respond to the dynamic market changes. The success of these firms relies on these competencies that are unique to the firm, which cannot simply be acquired and must be built and developed to respond to external changes. As stated by Teece *et al.* (1997:509) "*private wealth creation in regimes of rapid technological changes depends in large measure on honing internal technological, organizational and managerial processes inside the firm*". The BA analysis provides an insight in these resources and identifies changes that were induced at this level through the funded R&D project development that may have contributed to competitive advantages and consequent success of the firm in the market place.

On the other hand, the Value Innovation approach sees the Market as the path for the firm success, and considers that firms are more competitive when these can define strategies that allow them to enter new markets or develop new businesses (Georghiou and Clarysse, 2006). Following public incentive schemes, the firm can experience changes in its market strategy as a result of behavioural additionality effects (IDEA Consult, 2009).

Behavioural Additionality is often represented as a black box, between input and output additionality of R&D, which embarks all the changes that occur internally within the firm during this funded innovation process (Figure 1).

Figure 1. Behavioural Additionality.



Although the general concept of BA is accepted by most authors, there is still some controversy regarding its exact definition, the scope that it embarks and persistency of its effects. Based on several presented perspectives, the scientific community has recognized the existence of four possible categories for BA, as follows (Cerulli and Poti, 2012; Gok and Edler, 2012):

- An extension of input additionality with qualitative data, covering scale, scope, and acceleration additionality;
- A non-persistent change in the behaviour related to R&D and innovation activities;
- A persistent change in behaviour related to R&D and innovation activities;
- A persistent change in the general conduct of the firm, with reference to building blocks of behaviour.

Different authors evaluate and consider different dimensions to be part of BA. According to Georghiou (2002), a first division was proposed by the UK Department of Trade and Industry, and included three dimensions related to the funded project: Scale, Acceleration and Scope. These three dimensions are also generally designated as Project Additionalities (Davenport *et al.*, 1998). The Scale Additionality assesses if the funding allowed for a bigger project, which can comprise a larger team, more R&D activities, technology development up to higher Technology Readiness Level (TRL), etc. The Acceleration Additionality evaluates if the incentive promoted faster development, which may include shorter project development time, an earlier start, or shorter time-to-market

of the product. The Scope Additionality considers if the funding incentivised an expansion of the project ambition by increasing its complexity or technological scope, or by targeting new markets or research areas beyond the firm's standard activity; if this larger scope allows for a higher risk to be considered for the project, this can also be referred as Challenge Additionality (IDEA Consult, 2009). This form of additionality is highly regarded, as it can generate a more ambitious project with potentially higher innovative and economic impacts.

Bath and Matt (2002) proposed that there are two main perspectives in BA, a first that focuses on the Project Additionality, which is similar to the previous interpretation, and a second one that considers if after the project the firm will conduct R&D differently, considering changes into the knowledge base and R&D or management routines – which the authors designated by Cognitive Additionality. This evaluates if new knowledge acquisition or competence development within the project can be further applied beyond the project. Further sub-division into Management and Follow-up additionality have been applied, if new management skills are developed or acquired knowledge is applied to new projects. This dimension is associated with the Absorptive Capacity concept introduced by Cohen and Levinthal (1990) to explain organizational learning phenomena associated with R&D, which activities can enhance the firm's ability to assimilate new and exploit existing knowledge.

If project funding contributes towards the expansion of the firm's network, by establishing enduring new partnerships with public research organizations (PROs) entities for knowledge acquisition or strategic partnerships with firms, this can be referred as Collaboration Additionality. Collaboration is considered a central subject in BA studies, as these are seen as a means to develop internal competences and to share the project risk (Cerrulli *et al.*, 2016).

The BA effects can be further categorised within short-term (project duration) and long-term permanent effects (after project), to assess the persistency of the identified effects on the firm's conduct. Project additionality is generally only observed during project development, while Collaborative, Cognitive or Management additionality can be observed after project conclusion (Gok and Edler, 2012). The persistency of these effects is mainly associated with spill-over effects from knowledge, competences and

connections that were developed during the project and that can be extended to other projects or activities within the firm.

Clarysse *et al.* (2004) has further contributed to the BA framework by introducing different levels of differentiation to these dimensions, considering that BA effects can have impacts at strategic and operation levels, and can also be differentiated if these are contained within the project scope or can have impacts at firm level. The access to R&D public funding can allow firms to channel these funds onto riskier projects, which might entail entrance into a new market segment or conducting R&D in a new knowledge area, which may impact the firm's competitive strategy. These strategic impacts can include changes in market position and competitiveness, such as evolution from follower to market leader, entrance in new markets, forming strategic partnerships, expansion of R&D facilities or new areas of R&D intervention, etc (Clarysse *et al.*, 2004; Georghiou, 2004).

The behavioural additionality assessment is multi-layered and not easily evaluated due the intangible nature of information and lack of systematic available data (Falk, 2007). The first exhaustive study addressing BA was commissioned by the OCDE in 2006, which included the assessment of several public R&D funding programmes carried out in different countries, including evaluation of the EU FP5[2] (OCDE, 2006). This work, which identified several qualitative changes in the R&D conduct of firms as a result of public R&D funding, brought attention to this subject and encouraged subsequent studies of behavioural additionality by several scholars.

Behavioural analysis methodologies are generally based in two different approaches (Falk, 2007). One consists on the comparison of available data gathered from surveys and econometric analysis of beneficiary firms. This approached was used by Hyvarinen (2006) to assess the impact of Finish public R&D funding on firms' behaviour towards R&D activities. The author interpreted the behavioural changes in two different stages, during the project development and after its conclusion. The results evidenced that funding had a prolonged effect and contributed to improve firm competitiveness and capacity to conduct R&D, and also enhanced human resources skills and expanded their

[2] EU FP5 was The Fifth European Community Framework Programme covering Research, Technological Development and Demonstration activities.

networks. The impact of these results was regarded as important not only at firm-level but with implications for the Finish economy as a whole. This methodological approach has been applied by many researchers, using and adapting available data from econometric studies or surveyed data for BA study (Falk, 2004). One of the appointed limitations to this approach is that it is focused on information that is quantifiable, and not necessarily on the information that should be measured to appraise all aspects of public funding additionality.

The other methodology applied for BA analysis, is based in interviews performed to beneficiaries' firms to ascertain through a series of questions how their behaviour towards innovation changed (Falk, 2007). The advantage of this approach is the possibility to access and explore information about each firm's experience with the funded project, which due to subjectivity of behaviour could be more revealing than standardised surveys. A study performed in New Zealand applied this methodology to evaluate the attitude of managers of R&D funded of firms towards the effectiveness of these schemes, in particular, on external collaborations (Davenport *et al.,* 1998). An interesting finding was that managers highlighted the importance of the "disciplinary effects" brought to their firm's organization by the funded projects, and furthermore, that these effects extrapolated beyond the project and were sustained after its completion in R&D management. Funding obligations, such as work-plans, periodic reporting and project regular auditing activities, were appointed to have contributed to the development of this BA within the firms. Therefore, the way reporting and monitoring of funding application is set-up by the government could have positive reflections on firms' organisation towards R&D in the future, and prepare them to engage in further R&D activities in a more confident and structured manner. Applying interviews to this study also allowed to explore additional information that standard surveys cannot capture. Other authors have selected an interview methodological approach to evaluate different dimensions of BA within public funded firms (Clarysse *et al.,* 2006; Malik *et al*., 2006).

The majority of BA studies focuses on the Collaborative dimension. In a study performed on a German sample of subsidised firms, it was found that collaborations with academia were less likely to continue after funded projects ended, although collaborations with

firms were maintained (Fier *et al.*, 2006). The authors mention that collaborative projects are often linked to individuals and these may not be sustained if one drops out of the institution or firm. Also, the financial risk involved in collaborations with academia could be higher than sharing this risk with other firms. Another study on collaboration study took an organizational learning approach to study BA effects in a sample of firms benefiting from R&D subsidies in Flanders (Clarysse *et al.*, 2009). They found that the more experienced firms are in subsidised R&D projects, the more behavioural learning these will experience. Also, the more collaborations these firms have, the more these will learn in terms of management. They concluded that input and behaviour additionality correlated well, which is an indication that firms with more adaptable management approaches could also be more willing to engage in further R&D activities.

Another extensive BA assessment was performed by Falk (2007) with a sample of firms that benefited from an Austrian R&D funding programme. The surveyed categories included R&D activity, project size, time-frame, own R&D expenditure, cooperation, risk and research focus. They found that through the incentive about 40 to 50% of the firms increased its R&D activity, project size and time-frame, and that 30 to 40% of the firms increased own R&D expenditure, expanded cooperation and introduced more risk into the project. These results highlighted the impacts and contributions this funding programme had besides quantifiable output results. Also, according to the author, identifying the BA effects that emerge from these incentives and studying the firms more receptive to these effects, can support funding policy refinement and improve its efficacy.

As this literature review has shown, behaviour additionality analysis can provide valuable insight into how public subsidies can impact and mould firms' behaviour and innovation strategy. It is therefore appropriate to assess the permanent effects and behavioural changes that occur within the beneficiary firms' organization, which can empower them to engage in more innovation activities, beyond the particular subsidized R&D project, and improve the efficiency of their innovation processes. Together with input and output additionality analysis, this behaviour perspective provides a more thorough and comprehensive evaluation of public R&D funding, which can be valuable towards policy improvement and more efficient funds' allocation. To the best of our knowledge, there is

a lack of studies addressing this type of additionality within Portuguese experience on R&D public funding programmes. This is therefore a relevant perspective to explore and integrate in the evaluation of impacts that public R&D funding has on beneficiary firms, in the Portuguese context.

In the following section, a characterization of the Portuguese R&D performance is provided to contextualize the Portuguese business R&D evolution since 2000.

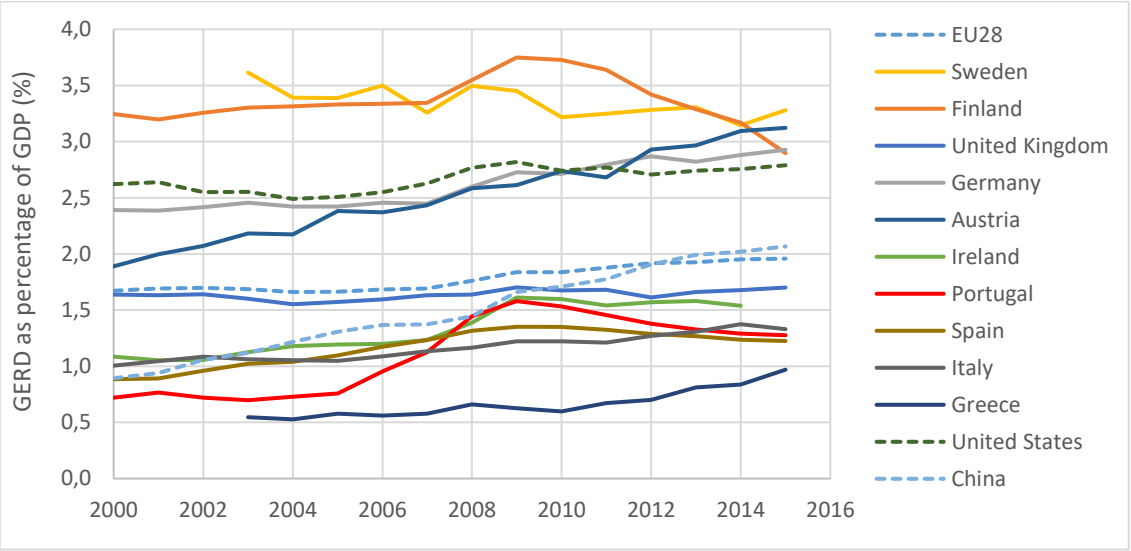
3. Characterization of Portuguese R&D Performance

3.1 Business R&D Evolution

Portugal was classified by the 2017 Innovation Union Scoreboard as a Moderate Innovator, with an innovative performance of 81% of the UE28 average (EU, 2017). Portugal stands currently at the lead of this Moderate group but since 2010 this performance level has not changed considerably, even declining by 2.4%, and is currently scoring below countries like Slovenia, Czech Republic and Ireland. The appointed strengths of the national innovation system are Innovation-friendly environment, Attractive research systems (above EU average on international scientific co-publications) and Human resources (above EU average on doctorate graduates). The identified weaknesses are Linkages (low collaboration between firms), Sales impacts (low high- and medium-tech exports, and low innovative products), and Employment impacts (low knowledge-intensive employment). The lowest scoring individual index categories (< 50% of EU average) are R&D expenditure in the business sector, Public-private co-publications, Private co-funding of public R&D expenditure, PCT patent applications and Sales of new-to-market innovations. These low scoring categories clearly highlight the weaknesses of the Portuguese business sector in the matter of innovation, and reiterate the lower intensity of firms' R&D activities when compared to many other EU nations.

The Portuguese gross expenditure in R&D (GERD), also referred as *R&D Intensity*, has increased in the last two decades from 0,76% of GDP in 2000 to 1,27% of GDP in 2016, with a sharp growth observed in the period between 2005-2009 (Figure 2). The national R&D intensity has not improved since 2009, and has been decreasing. Despite the catching up effort in the latest years, Portugal still stands behind the EU28 average GERD of 1.96% GDP (2015) and distant from the EU innovation leaders. Considering the national target set for R&D intensity of 2.7% of GDP by 2020, defined in agreement with the EU 2020 strategy, Portugal needs to double its R&D efforts in the next 4 years to be able to achieve this target (Pordata, 2017a). Due to this poor performance, Portugal has been included in a group of member countries that were recommended to "substantially raise their rate of increase in R&D intensity" (EU, 2012).

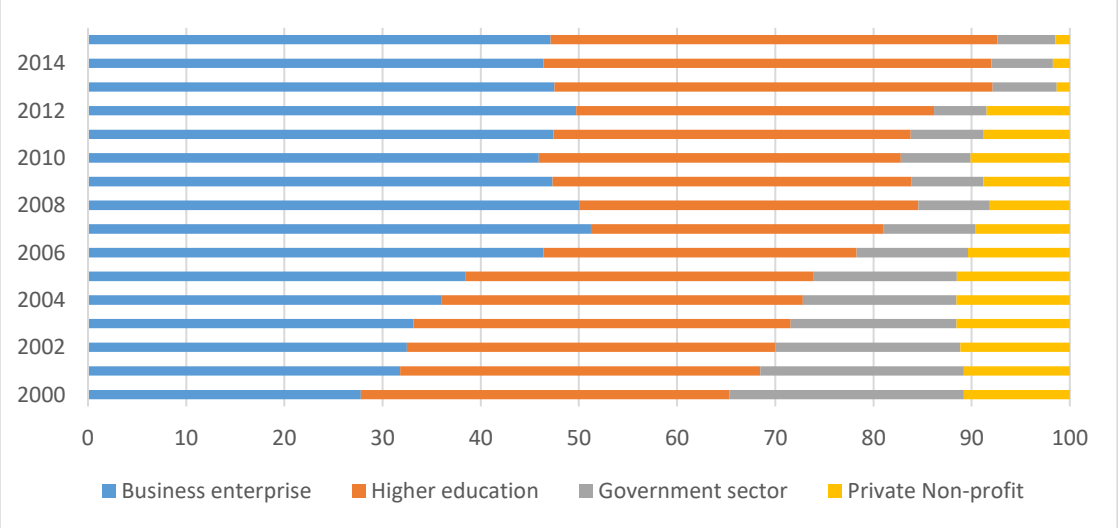
Figure 2. Total R&D expenditure from 2000-2015.



Source: OCDE, 2017

The national GERD can be split into different institutional sectors, such as government, business, higher education and private-non-profit (Figure 3).

Figure 3. Distribution of national GERD performed by sector (2000-2015).



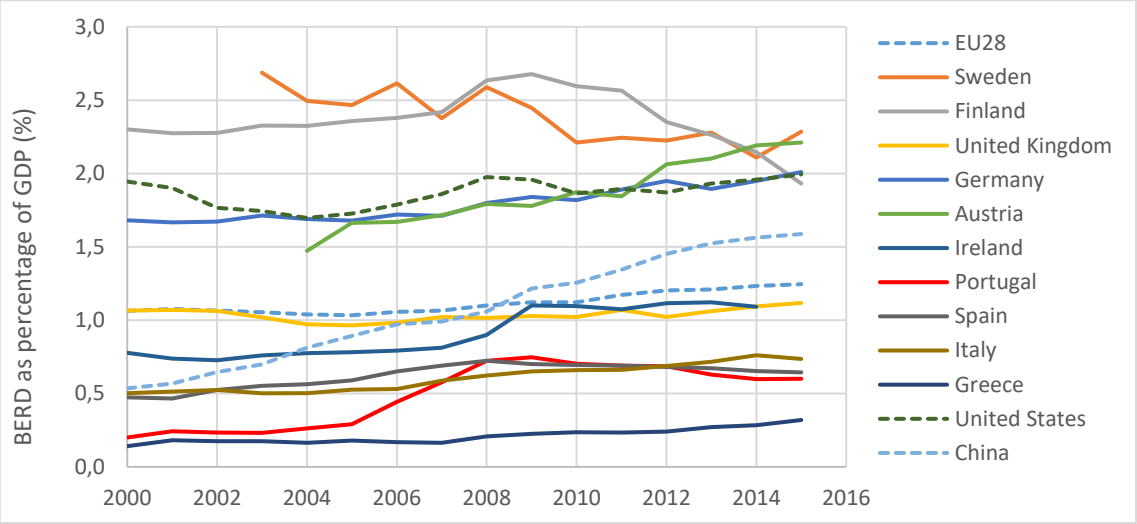
Source: OCDE, 2017

Analysing the contribution of each sector since 2000, the business share had a sharp increased from 2000 to 2007, but has since stabilized just under 50%. This shows that the majority of R&D is still carried out at universities and government facilities, which mainly consists of basic research. Innovations thrive from applied knowledge that is

mainly performed at business level, but the intensity of these activities has not been intensified when compared to R&D performed by other sectors in the latter years, which contributes to the low performance of the Portuguese innovative behaviour.

The Portuguese business expenditure in R&D (BERD) has been very modest when compared to other EU countries, although a considerable increase was observed between 2005 – 2008 from 0.3 to 0.7%, and has since stagnated at 0.6%, a value equivalent to half of the EU28 average (Figure 4). This profile shows that the Portuguese firms still have low propensity to invest in R&D, and thus to innovate, which is also reflected in the low competitivess of the business sector exhibited in the European and global context. In the latest Global Competitiveness Index Portugal was raked in the 46th global position, holding the 34th position in the Innovation Pillar with a score of 3.9/7 (WEF, 2017).

Figure 4. Business R&D expenditure from 2000-2015.



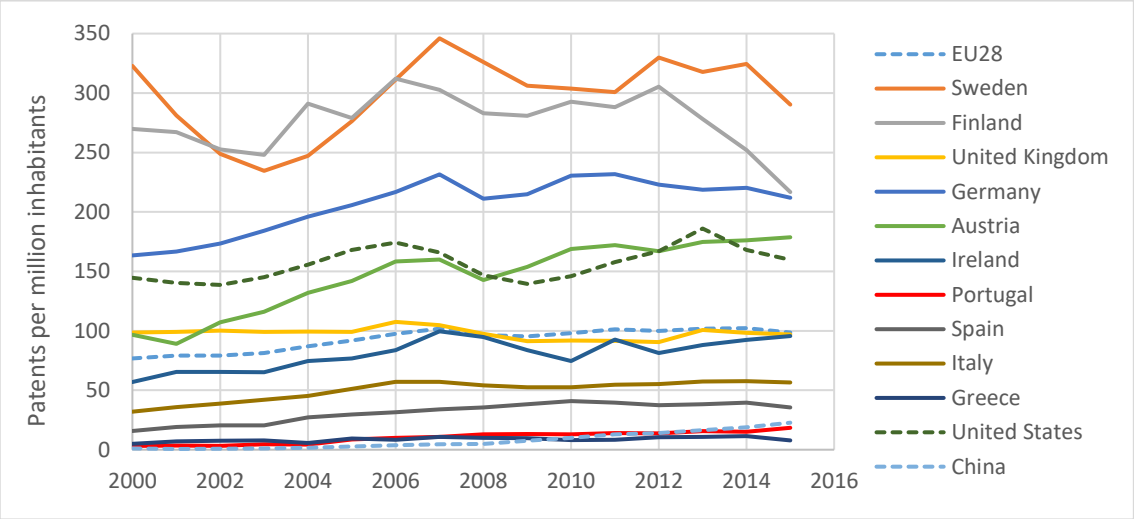
Source: OCDE, 2017

In the latest years, especially since the QREN in 2007, public R&D funding has been promoting business R&D through different initiatives, such as tax benefits and funding schemes, however these have yet provided a marginal improvement of the BERD. The fact that Portuguese GDP has seen negative growth rates in 2009 and between 2011 and 2013, has also negatively impacted BERD. The financial crisis can also promote a shift

of the firms' focus from its innovation strategy towards the maintenance and survival of their immediate core activities, contributing to reduced R&D investments.

The Portuguese patent filling record is also very modest compared to the UE28 average, with only 18 patents filled per million inhabitants in 2015 compared to the EU28 average of 98 (Figure 5). Although there has been an increase since 2000 (from 3 to 18 patents filled per million inhabitants) this record is still very far from other European technologically leading nations. This indicator clearly demonstrates the low innovation intensity observed among Portuguese firms, reflecting the lack of improved processes implement and innovative products brought to market.

Figure 5. Patent applications filled under PCT per million inhabitants.



Source: OCDE, 2017

A more detailed insight into the characteristics of the Portuguese business sector is presented in next section.

3.2 Sectorial R&D

The Portuguese business sector is mainly constituted by small and medium-sized enterprises (SMEs), with a total of 1.180.331 firms classified in 2015 as micro enterprises, with less than 10 employees, corresponding to a share of 96% of the total firms (Pordata, 2017b). The large firms account for less than 0,1% of the total firms, with 1.075 firms in activity in 2015 (Pordata, 2017b).

In terms of the R&D expenditure profile among Portuguese firms, the micro-sized only account for 4,2% of the total BERD (Table 1; IPCTN15, data from 2015). The medium firms perform the majority of the R&D expenditure, accounting for 42,6% of the BERD, while small and large firms account for 18 % and 35,1% of the BERD, respectively. Although the micro-sized firms dominate the Portuguese business sector, the majority of these have a very familiar-like structure traditionally inserted in sectors with low technology intensity. There are still some exceptions, like high-tech start-up companies. The share of public funding in micro-sized firms' R&D expenditure is the highest at 15,5%, showing that these firms R&D activities rely significantly on public subsidies due to their limited resources and lack of credit opportunities. For small and medium sized firms, this share is 10,2% and 4,8%, respectively, and for large firms this public contribution corresponds only to 2,6% of their R&D investments.

Table 1. Business R&D expenditure and funding source by firm size in 2015.

Firm Size[1]	R&D Expenditure (k€)	Share of Total (%)	Funding Source			
			Own (k€)	Public (k€)	Other[2] (k€)	Share of Public funding (%)
Micro	43.962	4,2	31.7320	6.825	5.404	15,5
Small	187.038	18,0	141.5070	19.044	26.486	10,2
Medium	441.398	42,6	368.918	21.210	51.269	4,8
Large	364.132	35,1	352.741	9.569	1.822	2,6
TOTAL	**1.036.532**					

Source: IPCTN15, data from 2015.

1 Classified only by number of employees as defined by Portuguese Decree-law n.º 372/2007.
2 Other funding sources include: other private institutions, higher education, investments from abroad and non-profit organizations.

The Services sector has the highest share of BERD with 57% and the Manufacturing sector performing 39,8% (Table 2). The Knowledge Intensive firms, especially the High-Technology Services, are the ones performing higher R&D expenditure among Services, which are mainly constituted by firms within the Engineering and Technology Sciences domain (Table 3).

Table 2. Business R&D expenditure by sector and Technology Intensity in 2015

Sector	Technology Intensity[1]	BERD (k€)	%
Manufacturing	High-Technology	106.958	10,3
	Medium-High-Technology	110.920	10,7
	Medium-Low-Technology	84.453	8,1
	Low-Technology	110.247	10,6
	SUB-TOTAL	**412.579**	**39,8**
Services	Knowledge Intensive - High Technology Services	256.175	24,7
	Knowledge Intensive - Financial Services	166.314	16,0
	Knowledge Intensive - Market Services	64.549	6,2
	Knowledge Intensive - Other Services	19.798	1,9
	Low Knowledge Intensive - Market Services	70.328	6,8
	Low Knowledge Intensive - Other Services	13.900	1,3
	SUB-TOTAL	**591.066**	**57,0**
Other	Other	32.886	3,2
TOTAL		**1.036.532**	**100,0**

1 – In accordance with the International Eurostat classification of Technological Intensity based on NACE Rev.2.
Source: IPCTN15, data from 2015.

Among the Manufacturing sector, the Medium-Technology firms are the ones performing higher R&D expenditure, which are also mainly constituted by firms within the Engineering and Technology Sciences domain. These are closely followed by the High-Tech and Low High-Tech firms belonging to the same domain.

These expenditure levels show that Knowledge Intensive and Technology based firms are the ones with higher R&D investments and therefore more engaged in innovation processes. These are mainly represented by firms within the Health, Engineering and Technology and Exact Sciences domains, which are, respectively, mainly represented by health sciences; mechanical and IT engineering; and chemistry and computer science (IPCTN15, 2017).

Table 3. Business R&D expenditure by Technology Intensity and Technological and Scientific Domain in 2015.

Technology Intensity		Technological and Scientific Domain (% of BERD by Technology Intensity)							
		Exact Sciences	**Natural Sciences**	**Engineering & Technology**	**Health Sciences**	**Agricultural Sciences**	**Social Sciences**	**Humanities**	**TOTAL**
Manufacturing	High Tech	11,3	0,2	37,3	**50,7**	0,2	0,2	0,0	100
	Medium High Tech	9,7	0,3	**89,1**	0,1	0,7	0,0	0,0	100
	Medium Low Tech	2,8	0,2	**96,4**	0,0	0,2	0,1	0,3	100
	Low Tech	7,5	2,3	**77,1**	0,1	7,7	2,4	2,8	100
Services	Knowledge Intensive - High Tech Services	25,3	1,6	**65,3**	4,8	2,1	0,9	0,1	100
	Knowledge Intensive - Financial Services	32,5	2,5	**38,4**	0,1	0,0	26,5	0,0	100
	Knowledge Intensive - Market Services	16,8	1,6	**69,3**	6,0	1,3	4,3	0,7	100
	Knowledge Intensive - Other Services	30,9	0,6	**38,1**	24,0	0,6	2,4	3,4	100
	Low Knowledge Intensive - Market Services	31,3	1,5	**35,2**	26,4	4,0	1,4	0,2	100
	Low Knowledge Intensive - Other Services	6,5	5,7	**42,4**	17,0	22,9	5,5	0,0	100
	Other	5,0	2,3	**79,0**	0,1	13,5	0,2	0,0	100

Source: IPCTN15, data from 2015.

4. Methodology

4.1 Research approach

The present investigation aims to contribute towards the evaluation of the impact the QREN SI I&DT instrument had on beneficiary firms. The adopted methodology is a combination of an analysis of existing quantitative data on the approval and execution of these incentives, and a case-study analysis of the impact these incentives had on a sample of beneficiary firms, which explores the additionality aspects of these incentives with particular emphasis on behavioural additionality.

The overview analysis of the SI I&DT approval and execution was based on published execution data, which was available from project execution and approval reports and databases by the National Operational Programmes (Regional PO and COMPETE) and also the National Scientific and Technologic Potential Surveys (IPCTN). Based on this data, a critical analysis was performed on several aspects of the SI I&DT performance.

The impact of the QREN SI I&DT instrument at firm level was evaluated through a dedicated case-study analysis. According to Eisenhardt (1989), the case study analysis is "*a research strategy which focus on understanding the dynamics present within single settings*". Therefore, this was considered the best strategy to study the R&D funding impacts within different firm realities, and best suited to study the behavioural additionality impacts. The methodology applied to collect data for the case-study analysis was the interview. This approach was considered the most effective to gather information regarding the behavioural impacts, which is by nature subjective and qualitative. This methodology approach has been used by other authors addressing the behaviour additionality (Clarysse *et al.*, 2006; Malik *et al*., 2006). This analysis was complemented by information provided by the firms and other published sources regarding each project execution.

In order to standardize the interviews performed to each firm but to allow some exploration of each topic, a semi-structured script was developed to assess different dimensions of behavioural impacts on the funded firm. The script was developed based on the literature review performed in chapter 2 and behavioural questionnaires reported in the literature (Clarysse *et al.*, 2009; Georghiou, 2004). The semi-structured interview script is presented in Appendix. After the interviews were conducted, the information

collected for each case-study was analysed for each additionality dimension and were summarized in an additionality matrix based on Clarysse *et al.* (2004), to sort the identified behaviour impacts at organization level, as strategy or operation, and according to its scope at project or firm level. Following the individual case-study analysis, a cross-case discussion of the identified additionalities was performed.

4.2 Case-study selection

The firm selection is an important step for the case-study analysis and the theory building process (Eisenhardt, 1989). Following the preliminary characterization of the sectorial R&D and the SI I&DT execution data, the firms selected for the case-studies were inserted in the Norte region of Portugal, which had the largest share of SI I&DT[3] co-financed investments. The majority of the SI I&DT projects approved were inserted in the typologies of Individual and Collaborative I&DT projects, and for this reason the firms selected were among this group. Since the QREN programme concluded in 2015, the selected funded projects have been formally finished for at least 2 years. Due to time constraints, only three case-studies were selected and evaluated, which introduced limitations and reduced the scope of the conclusions of this dissertation. The firm selection criteria considered two main characteristics that were identified to provide a representative sample of contrasting experiences that could enrich the discussion of this research:

- Dimension of the firm; it has been shown that incentives can have different impacts for SMEs and Large firms (Gonzalez *et al.*, 2005), therefore firms with different dimensions were considered;
- Technology intensity of the firm; as shown in the sectorial R&D characterization, firms from higher technological sectors have typically higher R&D intensity, therefore firms with different technological intensities were considered;

The firms were selected from QREN SI I&DT approved projects lists published by the national financing bodies National Innovation Agency (AdI) and National Agency for

[3] SI I&DT (Research and Technological Development instrument) was one of the QREN's instruments directed at firms to fund R&D projects and activities.

Innovation and Competitiveness (IAPMEI). A pre-selection of firm's that fitted the established criteria was made, and contacts were established in order to identify firms receptive to participate in this study. Following these contacts, three firms were selected for the case-studies which fitted the following profiles:

- Firm A: Small firm, from a low technology intensity sector with no previous R&D funding experience;
- Firm B: Micro firm, from a high-technology intensity sector with a start-up activity;
- Firm C: Large firm, from a high-technology intensity sector with many years of R&D experience.

For each firm, a funded QREN SI I&DT project[4] was selected for the additionality evaluation. All the selected firms were leader promoters of the selected projects. The interviews were conducted between June and August 2017, and had an average duration of about 2 hours. All interviewees were directly involved in the selected R&D project development, and were also involved in the strategic innovation management of the firm. Follow-up contacts were made to clarify and retrieve additional information. The firms' identities have been concealed at their request, which also allowed a more open and frank testimony. A description of the firms profile included in this case-study analysis and the characterization of the selected projects is presented next.

4.3 Selected firms' profile

Firm A is a small-enterprise in a low technology intensity sector established in 2002. It is an agro-food company with certified biological production mode that produces and commercializes fresh and dried produces. During the QREN period, this firm benefited from only 1 SI I&DT collaborative project as project leader, and had no previous experience with funding programmes (Table 4).

[4] I&DT Project refers to one of the project typologies available within the QREN SI I&DT instrument, which supports individual or collaborative R&D projects promoted by firms to develop new products or processes.

Table 4. FIRM A selected project description

Project typology	I&DT collaborative project (project leader)
Object	Development of a food product line with enhanced functional and sensory properties
Domain	Agro-food technology
Partners	2 Universities 1 Firm
Execution	2014-2015
Total Budget	214 k€ (total incentive 158 k€)
Funding	PO Norte
Interviewee	Chief Executive Officer (CEO)

Firm B is a micro-enterprise with high R&D intensity established in 2006. It is a technology based company with activity within Biotechnology and Engineering areas, including environmental and chemical engineering. The firm's activity kick-started with a funded project from the NEOTEC[5] programme for new technology companies. During the QREN period, this firm participated in 5 funded I&DT projects in co-promotion (3 projects as project leader), and the following analysis was based on the first QREN SI I&DT project that was awarded to this firm (Table 5).

Table 5. FIRM B selected project description.

Project typology	I&DT collaborative project (project leader)
Objective	Development of an environmental treatment technology up to pilot scale
Domain	Environmental technology
Partners	1 university
Execution	2010-2012
Total Budget	220 k€ (total incentive 158 k€)
Funding	PO Norte
Interviewee	CEO, which was also the Project Manager (PM)

Firm C is a large firm with high R&D intensity established in 1948, integrated in a business group that ranks in the national top 20 of business R&D expenditure. It is a

[5] NEOTEC (Technology-based companies) was a national funding programme directed at Technology-based start-up companies during 2005-2006.

technology based corporation supplying products and systems with high added-value for infrastructural sectors as Energy, Environment & Industry and Mobility & Transportation. It has a strong exporting profile and international presence in over 65 countries. During the QREN period, this firm participated in a total of 35 funded SI I&DT projects, with 15 Individual I&DT projects and 20 collaborative I&DT projects. The case analysis was based on an Individual I&DT project (Table 6).

Table 6. FIRM C selected project description.

Project typology	Individual I&DT project
Objective	Development of a new control system for low voltage electric grids
Domain	Energy and Electric engineering
Partners	University was subcontracted
Execution	2012-2014
Total Budget	1.600 k€ (total incentive 880 k€)
Funding	COMPETE (POFC)
Interviewee	Firm Innovation & Technology Director, which was also the Project Manager

5. QREN Framework

5.1 Instruments Description

Since Portugal joined the EU in 1986 it has been receiving funds, as part of the European Cohesion Policy, to promote the economic, social and regional development, and bring Portugal closer to its EU more developed counterparts. These funds have been negotiated and transferred in five packages since 1989 (IFDR, 2009; PT2020, 2015).

In the period between 1989-2006 Portugal benefited of over 50 000 million Euros of EU funding through the three programmes QCA[6] I, QCA II and QCA III, which significantly contributed towards the economic, societal and regional development (Observatório QREN, sd). The current funding framework programme running in Portugal with a programming period between 2014-2020 is the *Portugal 2020* (PT2020), corresponding to an agreed EU funding package of 25 000 million Euros (PT2020, 2016).

The preceding funding framework, which started in 2007, was the National Strategic Reference Framework (QREN) set-up to manage the application of the EU's policy funds for the 2007-2013 programming period. This framework had a total investment of 44 374 million Euros, with EU co-funding of 21 511 million Euros (Sarmento, 2009). The main strategic guidelines for this programme were "*the qualification of the Portuguese people through an emphasis on knowledge, science, technology and innovation, as well as the promotion of high and sustained levels of economic and socio-cultural development and territorial qualification within a framework of expanding equal opportunities and increasing the efficiency and quality of public institutions*" (QREN, 2007). This framework was divided into three major thematic operational agendas: The Human Potential Agenda (total budget of 9 292 million Euros), The Territorial Enhancement Agenda (22 915 million Euros), and The Competitiveness Factors Agenda (11 871 million euros).

[6] QCA (Quadro Comunitário de Apoio) were the "Community Support Framework" programmes that managed the cohesion funds during 1989-2006.

During the QREN period, as well as for the current PT 2020 period, Norte region was classified as a convergence or less developed region, along with the Centro and Alentejo regions, which have been awarded a higher budget in comparison with other regions of Portugal mainland.

Within the QREN framework there was a set of public incentives initiatives specifically directed at firms to promote production of new knowledge and technological development, aiming to raise firms' productivity and competitiveness. One of these instruments made available to firms was the Research and Technological Development (SI I&DT) scheme. This instrument was important to address the national deficit in business R&D which was pointed out in the QREN partnership agreement document as one of the most worrying aspects of the Portuguese NIS, together with the lack of interactions with the other relevant NIS institutions (QREN, 2007). Also, it was pointed out that the prevalent business growth model had been centred on physical capital investments in detriment of immaterial investments, such as innovation and human resources development, rendering firms' inferior competitiveness and economic growth compared to the majority of EU countries.

In this context, the specific objectives defined for the SI I&DT instrument were the following:

- Intensify the national business R&D efforts;
- Improve firms' competitiveness through new knowledge creation;
- Promote firms' participation in international knowledge networks;
- Stimulate the creation and assimilation of new knowledge capable of inducing new economic opportunities;
- Promote cooperation and projects between firms and higher education research centres;
- Stimulate technological experimentation, demonstrative actions within the industrial sector, and technological dissemination and transference to this sector.

The beneficiaries of this instrument were primarily firms, which could also collaborate with PROs and business associations in some collaborative projects. Within the SI I&DT there were different project typologies as shown in Table 7.

Table 7. Main project typologies supported by the SI I&DT instrument.

Project Type	Aim
Individual	R&D projects for development of new products or services carried out solely by the firm;
Collaborative	R&D projects for development of new products or services carried out in collaboration with other firms or research institutions;
Mobilizing	Development of high technological and innovation profile projects with significant sectorial or regional impacts;
I&DT voucher	Contracting R&D external services from research institutions;
I&DT Nucleus	Creation of internal R&D competences;

The incentives awarded under this instrument were all non-refundable, within certain maximum levels defined for each project type. The base incentive share was 25% for the individual, collaborative, mobilizing and nucleus project typologies, and 75% for I&DT vouchers. These percentages were subjected to accretion depending on the firm size and nature of R&D activities, up to a maximum of 75%.

5.2 SI I&DT approval and execution

The projects under the SI I&DT instrument were managed by Operational Programmes at national and regional levels, namely the COMPETE (POFC) and Regional Programmes (PO), respectively. The projects promoted by micro and small sized firms were managed by the Regional PO of the region where the promotors were based, while projects promoted by medium and large firms were managed by COMPETE. The projects developed by multi-regional promotors were also managed by COMPETE, regardless of firms' size.

At regional management level, the SI I&DT projects promoted by micro and small size firms were concentrated in the Norte and Centro Regions of Portugal, with 414 and 389 projects approved respectively, followed by 208 projects in Lisboa Region (Table 8). A total of 227.626 thousand Euros was awarded under the Reginal POs to support SI I&DT projects, with the Norte region receiving the highest amount, but closely followed by the Centro and Lisboa regions. Considering the regional investments and number of projects approved, it can be seen that the average project budget in the Norte region was about

half the budget allocated per project in Lisboa region, which shows that the projects in the Norte had smaller dimension.

Table 8. SI I&DT projects' approval and total incentive awarded by the Regional POs (data from 2014).

Regional PO	Nº. Projects Approved	Total Eligible Investment (k€)	FEDER Incentive (k€)
Norte	414	111.609	72.470
Centro	389	112.574	70.862
Lisboa	208	126.542	71.101
Alentejo	34	11.657	7.257
Algarve	27	8.785	5.936
Total	**1.072**	**371.167**	**227.626**

Source: Execution reports of Regional POs: ON2 (2015); MAISCentro (2015); PORLisboa (2015), INAlentejo (2015); PO Algarve21 (2014).

Under the COMPETE, the projects promoted by medium and large firms were also concentrated in the Norte region with 309 projects, followed by the Centro region with 211 and Alentejo with 24 (Table 9). Under the COMPETE there were also 284 projects developed in multi-regions. The Norte region concentrated the higher investment with 432.951 thousand euros and 182.408 thousand euros of FEDER incentive awarded, followed by the Centro and the multi-region projects.

Table 9. SI I&DT projects' approval and total incentive awarded by the COMPETE.

COMPETE	Nº. Projects Approved	Total Eligible Investment (k€)	FEDER Incentive (k€)
Norte	309	432.951	182.408
Centro	211	127.666	63.378
Alentejo	24	11.641	5.480
Converging Multi-region (Norte, Centro e Alentejo)	164	123.228	81.056
Converging Multi-region and spillover effects (Norte, Centro, Alentejo, Lisboa e Algarve)	120	139.069	92.468
Total	**828**	**834.556**	**424.790**

Source: COMPETE execution report (2015).

The distribution of SI I&DT investments by industry's technology intensity, awarded under the COMPETE, shows that the manufacturing sector concentrated about two thirds of the funding, with the Medium-high-technology industries absorbing the highest share of this funding (Table 10; Silva and Silva, 2016). Within this sector, firms across several levels of technology intensity were funded, which shows that the SI I&DT supported a broad range of firms. The service sector concentrated a third of the total SI I&DT investment that was mainly used by knowledge-based services. By contrast, it is interesting to observe that the national BERD distribution by sector and technology intensity shows that the Service sector has a higher R&D performance with 57%, when compared to the Manufacturing sector that has 39% (Table 2). As Table 2 shows, the Service sector's BERD is dominated by financial services, which by nature have low technology demand and might explain this contrast.

Table 10. SI I&DT project and investment distribution by industry's technology intensity

COMPETE SI I&DT	**% of projects**	**% of investment**
Manufacturing Industries	**62,9**	**66,6**
High-technology industries	1,6	24,1
Medium-high-technology industries	26,0	19,7
Medium-low-technology industries	14,4	11,0
Low-technology industries	20,8	11,9
Services	**33,2**	**31,2**
Knowledge-based services	30,1	27,3
Other services	3,1	3,9
Other Industries	**3,9**	**2,2**
TOTAL	**100,0**	**100,0**

Source: Silva and Silva (2016).

Within the SI I&DT project typologies, the Individual and Collaborative I&DT projects were the most prevalent typologies accounting for a total of 1.337 projects, which corresponded to 70% of the total funded SI I&DT projects (Table 11). These projects are directed to the development of innovative products, processes or services within firms, and thus have a great potential to create a more significant and direct impact in firms' innovation and competitiveness. Within these two typologies, the individual projects were preferred by the firms, in particular among the micro and smaller firms funded by the

regional POs. Overall, the SI I&DT execution numbers clearly show that the Norte region benefited from the higher number of I&DT projects, with a total of 480 under the Regional PO and the POFC, and also concentrated the higher share of the total investment for this project typology (individual and collaborative).

Table 11. SI I&DT Individual and Collaborative projects

Project typology	**Collaborative**		**Individual**	
Operating Programme	**Nº. Projects Approved**	**Total Eligible Investment (k€)**	**Nº. Projects Approved**	**Total Eligible Investment (k€)**
PO				
Norte	88	36.172	133	44.572
Centro	68	26.518	112	37.258
Lisboa	54	30.108	135	75.815
Alentejo	2	955	18	6.009
Algarve	16	6.962	4	793
Sub-TOTAL	**228**	**100.718**	**402**	**164.449**
POFC				
Norte	83	67.102	176	118.072
Centro	62	42.878	106	60.437
Alentejo	2	573	18	8.818
Multi-Region	249	143.902	11	6.212
Sub-TOTAL	**396**	**254.456**	**311**	**193.540**
TOTAL	**624**	**355.174**	**713**	**357.990**

Source: QREN (2016).

To evaluate the configuration of the collaborative SI I&DT projects, a comparison was made between the projects awarded by COMPETE, mainly promoted by medium and large firms, and by the PO Norte, mainly promoted by micro and small firms (Table 12). For both cases, the collaborations were mainly formed by at least one firm (leader promotor) and a PRO. Very few projects were developed exclusively between firms, but within the PO Norte 26 projects with PROs were conducted with more than 1 firm. The same analysis could not be performed for the COMPETE funded projects due data availability issues.

Table 12. Configuration of SI I&DT collaborative projects for COMPETE and PO Norte.

Co-promotors	COMPETE[a]	PO Norte
Only Firms	17	2
Firms + Public research organizations	213	86
Firms + Business Associations	51	---
Firms + Non-profit Organizations	16	---

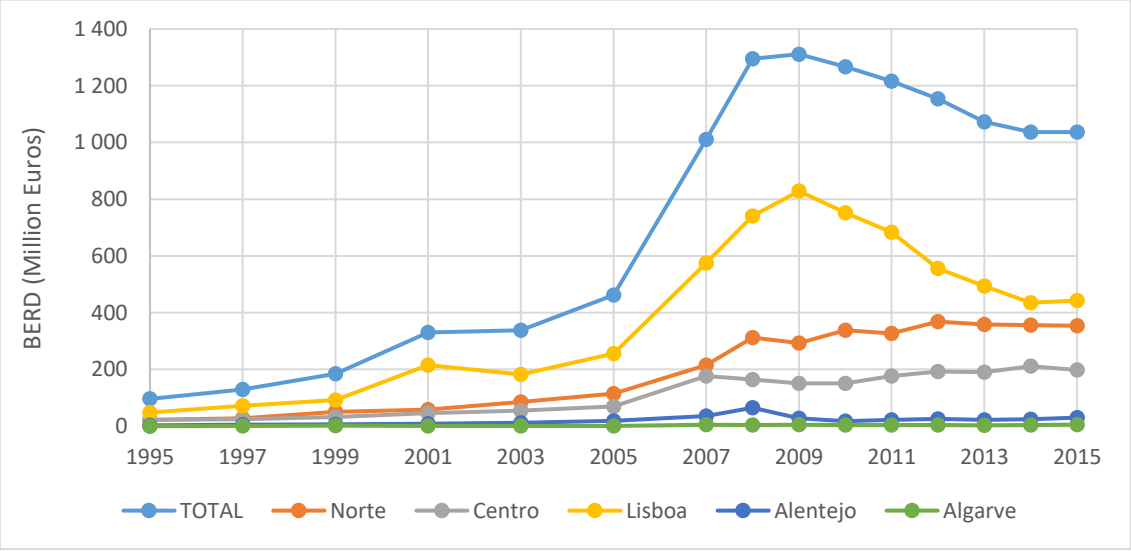
Source: COMPETE: Silva and Silva (2016); PO Norte: QREN (2016), AdI (2016).

[a)]Note *from* Silva and Silva (2016): "*Whenever a project includes at least two co-promoters from different categories and, additionally, a non-profit organisation, we have disregarded the non-profit organisation for classification purposes."*

5.3 SI I&DT Considerations

During the QREN period, the national BERD increased between 2007-2009, although it then decreased gradually to values close to the ones observed in 2007 (Figure 6). This trend shows that the SI I&DT had a considerable contribution towards the intensification of the R&D activities performed by the firms, and across a wide range sectors with different technologies intensities.

Figure 6. Evolution of the Portuguese Regional BERD performed by NUTII



Source: IPCTN

Although a negative trend has been observed in the overall national BERD since 2009, the Norte and Centro regions have counteracted this tendency, with a slight increase observed for the Centro region and a significant increase for the Norte region, which almost doubled its BERD from 215 million euros in 2007 to 355 million euros in 2015. These indicators show that despite the recession climate Portugal experienced since 2007, the Norte and Centro regions clearly amplified its investment in R&D. This tendency shows that the intensification of business R&D, which was one of the objectives of the SI I&DT, was accomplished in these converging areas.

The overall SI I&DT public incentive under COMPETE was the double of the incentive awarded under the Regional POs, which shows that a higher fraction of the public R&D funds available during the QREN were directed towards medium and large firms. These firms have higher productive capacity and the internationalization of innovative goods can have a great economic impact through increasing exports. It has been shown that there is a strong correlation between the SI I&DT funded firms and export performance, which highlights the impact of this instrument for internationalization of firms with products and services of high technological value (AMA, 2013).

The SI I&DT was very effective in promoting collaborations between firms and PROs, with 43% of the projects carried out in collaboration with one or more PROs. The PRO mainly perform basic research and are a valuable source of new knowledge for firms to support their applied research to develop novel products or processes, therefore collaborations between these institutions are desirable within NIS and are encouraged by public funding schemes. It is noteworthy that among micro and small firms, the individual projects corresponded to two thirds of the total funded projects, which suggests that these firms did not take full advantage of collaborations to improve their networks and explore external knowledge sources. Still, the SI I&DT promoted a much higher rate of collaborations between business and academia than the SAESCTN[7] scheme directed at PROs that run in parallel during the same period, where only 3% of the projects included a firm (Silva and Silva, 2016). This pattern suggests that SI I&DT funded firms were keen to engage in these collaborations with PROs to access new knowledge aligned with their

[7] SAESCTN, "Science and Technology Organizations Support System", was another incentive system directed to PROs that run in the programming period as QREN2007-2013.

R&D strategy, while PROs funded by the SAESCTN were more eager to explore connections within academia rather than search for opportunities to apply their research (Silva and Silva, 2016). This comparison exalts even more the SI I&DT impact in creating more linkages between firms and academia, which was one of the objectives set out. The collaborations between firms in the SI I&DT were less intense, which shows that firms are still reluctant to engage in strategic partnerships to leverage its R&D performance and improve its competitive strategies.

6. Case-study analysis

This section presents the results of the case-study analysis of the information collected from the interviews performed to each firm, with transcripts of the interviewee's statements. Following the individual case-study analysis, a cross-case discussion of the identified additionalities is presented.

6.1 Results

6.1.1 FIRM A – SME with low technological intensity

The interview was conducted with the firm's CEO that was also closely involved in the I&DT project development. Regarding the strategic motivations for this project, the development of the SI I&DT funded project by Firm A was a strategic decision to support a business model change in the Firm. According to the CEO, "*up to 2013 the firm was mainly producing fresh agro-products, which we exclusively exported directly to a distributer; from 2013 onwards we decided to change our strategy by retaining our production and developing our own products, doing everything from seed to product development and commercialization*". The CEO added that "*this project was a chance for the firm's rebirth*". With this change the firm started approaching the internal market as well and expanded their work force. The main motivations for developing this I&DT project were twofold, as the CEO pointed out: i) "*enter a new market segment to support the firm's business model change, and ii) to develop a premium product line to elevate the consumption's sensory experience of this range of products*". This second motivation is related to fact that the firm recognized they lacked the scientific knowledge to characterize the sensory product's properties to validate the product development that was required for this premium line they wanted to develop. So strategically they looked for PRO partners that could bring this knowledge and competences to the I&DT project.

In relation to the project input additionality, the CEO clearly stated that without this funding they would not have developed the project – "*we did not have the scale to do this, and it would be impossible to allocate or recruit 1 human resource (HR) full time to this development*". The awarded funding was therefore determinant for this R&D project development, and full input additionality was observed. The project budget was mainly

allocated to cover HR costs. Before this project, the firm had no R&D expenditure or experience, and during this project they made an investment corresponding to the non-supported share of the project investment. After project conclusion, the firm has not applied to other R&D funding opportunities projects nor made significant additional R&D investments. However, the CEO stated they would like to follow-up this R&D project with their partners, but not for the time being as they have many other activities related to the firm's expansion going on.

With regards to collaboration additionality, the firm already had some previous contact with one of the project' PRO partners, but through this project this collaboration was strengthened and another PRO partnership was established. According to the CEO " *these collaborations were fundamental to create knowledge to support the development and validation of the products to achieve exceptional properties; this knowledge is at the base of the products' continuous international recognition since 2014*". The knowledge generated in the project has been applied internally by the firm to develop services. In this case, the collaboration additionality resulted in the absorption of new external knowledge. There have been some occasional follow-up contacts with these partners, but no formal collaboration has been continued after the project concluded. However, the CEO added that collaborations with PROs are still a valuable source of knowledge through the several Master projects they host, and have since this project become more aware and involved: "*we only select research topics we consider strategic and impose that the students work on our premises, so we can learn from this research*". The firm also established a new partnership with a firm for product packaging development and design validation. The CEO added that "*this project brought visibility to the firm and was a catalyst for many cross-branding partnerships we currently have across the food industry*".

As an agroindustry, most of the firm's HR have low qualifications. With this project, the firm had the opportunity to hire a qualified HR that was fully dedicated to R&D during project development, and that remained in the firm after its conclusion mainly dedicated to product development, among other tasks. Before this project the innovation in the firm was inexistent, since it was mainly a raw material supplier for other businesses. During

the project, the firm instituted a project manager for this development (new HR), who was dedicated full time to the project, but after project conclusion there were no permanent changes made in the organization to maintain a permanent innovation team or R&D activity. On this point, the CEO stated that "*we are a small team and we are constantly multitasking to get what is needed done*". However, he recognizes that through this experience they became more conscious of innovation and have adapted behaviours to manage more easily product development. The firm currently carries out some occasional product development, to increment product lines, with the knowledge apprehended in the project, but with very low intensity.

The main output of the project for the firm was according to the CEO: "*the development of a new premium product line that is unique worldwide, with 5 products highly recognized in the most prestigious international food awards every year since 2014, which brought us a lot of recognition; additionally, this project promoted the creation of services such as workshops and masterclasses which all have been supported by the knowledge we apprehended, and are in high demand".* The new product line has leveraged the internationalization of the firm in this new market segment, and its economic impact currently corresponds to over 30% of the firm's turnover, which shows that the incentive had a significant contribution towards supporting the business model change. The CEO concluded that "*the funding supported the firm's business model change and boosted our operation in a new market segment with this premium product*".

A summary of the identified incentive additionalities for Firm A is presented in Table 13. At strategic level, the most relevant impact of the project corresponded to the change in the competitive strategy of the firm, since the new products allowed the firm to change its business model and start competing by product differentiation in a new market segment. The new products brought huge visibility to the firm through the several international awards received through firm's initiative, which impacted their reputation. The collaborations established were also considered strategic as these were sought by the firm to capture specialized knowledge that was critical for product development, although these were not sustained after project conclusion. At operation level, the firm's innovation awareness was improved with the project, as a result of a first R&D experience, but there

were no significant long-term impacts in the internal organization to support a more formal or persistent R&D activity. With the funded project, the firm hired a qualified HR and acquired new knowledge, that had a persistent impact at firm level since the HR was maintained and the knowledge integrated in further services.

Table 13. FIRM A: SI I&DT project additionalities

Input Additionality		Increased R&D expenditure	
		Project Level	**Firm Level**
Behaviour Additionality	**Strategy**	▪ Collaboration with PRO partners	▪ Business model change ▪ Entrance in new market segment ▪ Reputation (awards)
	Operation	▪ Full Project Additionality (scope, scale and acceleration)	▪ Innovation awareness ▪ Upgrade HR team ▪ Cognitive: new knowledge
Output Additionality		▪ Novel products and services; ▪ Profitability	

Source: Matrix adapted from Clarysse *et al.* (2004).

6.1.2 FIRM B – SME with high technological intensity

The interview was conducted with the firm's CEO that was also the Project Manager (PM). Regarding the strategic motivations for this project, the PM stated that as a start-up firm with high R&D activity it was very important to secure public incentives to launch the firm and finance its early activity: "*the period between 2006-2010 was critical to establish the workforce and to formalize the firm's position in the market*". The main motivations for this particular project were, according to the PM: "*to expand the technology portfolio to a new area, increase the turnover, and to establish a strategic partnership with a large firm, which manifested interest in this technology*".

The awarded subsidy allowed for an increase in the R&D expenditure of the firm, so incentive input additionally was observed. If the project had not been subsidized, the firm would still carry out some development, as the project was deemed strategic at the time for the firm´s activity, but with a significantly lower budget, as the PM stated: "*the firm had a prototype that could be adapted for this development with low investment, however*

without a fully dedicated HR the scope and complexity of the project would have to be considerably reduced". Most of the project budget was allocated to hiring highly qualified HR, which according to the PM: "*allowed for a closer technical and dedicated development of the project, which was determinant for the technology successful development and further expansion of this business area*". The decision to start the project was only taken after the call results were received, and in case of a negative outcome, the terms of the project development would be revised at that stage. It also noteworthy that the incentive provided a diversification of funding sources to finance the firm's early activity.

In relation to the project additionality, the subsidy clearly contributed to a larger scope and scale of the project, as without funding the project would still be carried out but with significant changes at these levels, as the PM stated: "*simplified research approach, less performance monitoring, and smaller scale*". The funding allowed the firm to take a bigger technological risk in this project, by carrying out part of the development at pilot-scale. Therefore, with the funding, the firm was able to develop a technology until a higher technology readiness level (TRL), which allowed it to get more reliable results to approach the market. The subsidy of the project allowed for a faster development, since dedicated HR were running the project. Therefore, high project additionality, including challenge additionally, was observed as a result of the awarded subsidy.

With regards to cooperation with other entities, the firm had already collaborated with the university that became co-promotor, but through this project this connection was intensified. The collaborations with PROs entities are recognized by the firm as sources of new knowledge, as the PM stated: "*we always look for PRO partners that hold specific knowledge or competencies from whom we can learn, to complement our own knowledge base in order to respond to challenges we embrace, either for large collaborative projects or internal ones*". This project was also an opportunity for the firm to capture the interest of a large firm as a strategic business partner, as highlighted by the PM: "*following the results achieved, a business partnership was formalized with a larger firm, which was important to leverage and support the industrial scale development and market approach*". This strategic partnership was celebrated after the firm achieved successful

results in the project, therefore the awarded incentive promoted this partnership and also the intensification of the relations with a PRO. These collaborations were maintained by the firm after the project finished through subsequent R&D projects and business relations.

The PM stated that "*the most valuable asset of the firm are its people*", referring to the fact that their highly skilled and knowledgeable team is determinant for the firm' success as a R&D performing SME. The firm had already 2 PhD's in their team with a strong background in R&D, and with this project the firm recruited and additional PhD and a masters graduate, both with R&D experience in the project area, which have remained in the firm after project conclusion. The project allowed the firm to enhance the knowledge base it had, as the PM pointed out "*we acquired new knowledge mainly from the research we conducted, but also through contact with the project partners*". The firm had a follow-up project where it applied much of the basic knowledge acquired in this project to a different technological application, thus it transferred the acquired in this funded project in follow-up developments. The PM highlighted that: "*without the funding, the firm would not have had the chance to form a capable team to advance with this technology, and further developments in this specific business area*". Therefore, the expansion of the HR team supported by this incentive was very strategic for the firm to enhance its knowledge stock and develop a new market area.

At management level, during the development of this project the firm implemented the NP4457:2007 R&D and Innovation standard. According to the PM: "*the innovation culture of the firm was strengthened by this process (…) there were already innovation practises internally but not very formal, but through these funded projects this process gained more structure, especially with the NP4457 certification and the expansion of the R&D team*". There was an investment in the HR innovation skills with specific training for the NP4457:2007 implementation process. At the organization level, an innovation management team was created within the firm during the implementation process, which is responsible for the discussion of new project ideas, partnerships, progress of ongoing projects, etc, and the decisions on new R&D projects.

The main output of the project for the firm consisted in the development of a new technology at pilot scale. Regarding the economic impact, the PM stated that: "*it is still not very significant due to the fact that we have recently concluded the industrial scale technology validation, which was a critical step to achieve performance results to approach the market*". In conclusion, the PM stated that: "*from a strategic point of view, we were able to enter a new business area with a technology that differentiates us from the competition; also, we established a strategic partnership with a larger firm that reviewed and valued our results, which was important to secure financing for industrial scale-up and credibility for the market approach*".

A summary of the identified incentive additionalities for Firm B is presented in Table 14.

Table 14. FIRM B: SI I&DT project additionalities

Input Additionality		Increased R&D expenditure	
		Project Level	**Firm Level**
Behaviour Additionality	**Strategy**	▪ Strategic partnership with larger firm ▪ Expanded highly qualified HR team	▪ Enter new technological domain ▪ Future innovation potential ▪ Diversification of funding sources
	Operation	▪ Faster development time ▪ Larger scale ▪ Larger scope and higher risk ▪ Collaboration with PRO partner	▪ Formalised innovation process ▪ Cognitive: Improved innovation management capabilities and stock of knowledge
Output Additionality		▪ New technology; ▪ Profitability (expected at full scale)	

Source: Matrix adapted from Clarysse *et al.* (2004).

Being a start-up firm with a pronounced core R&D activity, the awarded incentive for this project had a significant strategic impact. The incentive allowed the firm to consolidate its activity and implement a competitive strategy based on the development of innovative and differentiated technologies to meet the needs of a specific market segment. The firm tackled a new technological domain it saw has having potential do

expand further into other innovations, with follow-up projects currently under development. The incentive allowed this start-up to diversify its funding sources and secure much needed capital to support its early activity, which was crucial for the firm subsistence. The exploration of available R&D incentive funds is a constant practice explored by the firm to fund its larger R&D projects. Securing a long-term strategic partnership with a leading firm was also an important impact of the project, which was crucial for the scale-up stage and to leverage the market approach. Also, the consolidation of a highly-qualified R&D team was also a significant impact at strategic level, since these HR developed this business area and were dedicated to follow-up projects made possible through the knowledge these brought to the firm and further developed through this project. At operation level, a large additionality at project level was observed, including faster development time, larger scale, larger scope and higher risk. The firm's innovation processes became more structured and formal following the project, especially with the implementation of the NP4457:2007, and also through the development of new innovation management capabilities.

6.1.3 FIRM C – Large firm with high technological intensity

The interview was conducted with the firm's Innovation & Technology Director that was also the Project Manager (PM). This firm has been performing R&D for over 30 years and according to the PM: "*innovation is very strategic for the firm since our market positioning is to compete through product differentiation and not by price*". The main strategic motivations for developing this I&DT project, as appointed by the PM, were: "*decision to target a market segment before our competitors, develop a credible and innovative product with ubiquitous market acceptation both at national and international levels, and to capitalize in-house existing competences in this technological area while recruiting additional specialised HR*". The decision to develop R&D projects is taken internally after a planned and sequential validation process of the initial idea, which involves state-of-the-art characterization, contacts with potential partners, and extensive market and trends research. This is a decision process based on strategic decisions of the firm, and independent of existing public funding opportunities. According to the PM, the firm then looks for public funding for its projects for three reasons: "*i) reduce the project*

technological risk, ii) increase the technological scope of the project, and iii) to constrict product development time".

The firm has a high R&D expenditure and sets its R&D budget annually according to the projects that have received the "go" from the innovation and technology office. The awarded subsidy for this I&DT project allowed the firm to slightly increase the overall budget of the project, thus increasing the overall R&D expenditure of the firm, but it also replaced a great part of the firm's pre-allocated R&D budget. For this reason a partial crowding-out effect was observed with regards to input additionality of the incentive. About 50% of the project budget was allocated to HR, and 40% to subcontracting a university.

If the project had not been subsidized, the firm would have still developed the project with a slightly lower budget, longer development time, and assuming a lower technological risk (reduced scope). Thus in terms of project additionality, the subsidy allowed the firm to consider a higher technological risk in this project and to increment the scope ambition by exploring additional functionalities, while reducing the time to market of the developed product.

Although this was an I&DT individual project, the firm collaborated in this development with a university by subcontracting its services, and also consulted with a potential client. These collaborations were pre-existent and have been maintained through follow-up projects. The firm values and maintains several external collaborations that can either complement their knowledge in different technological areas, or that can provide additional input on market needs (potential clients).

The firm had a large team allocated to this project, which included in-house engineers and recruited highly qualified HR to reinforce the project's team. According to the PM: "*the HR were exclusively dedicated to R&D activities to maintain focus on these tasks, and avoid distractions with other operational activities*". The new HR have been maintained after the project, and the firm is currently recruiting more staff for this specific technological area, as highlighted by the PM: "*this particular area has revealed to be*

critical for this business unit". The knowledge developed in this project has been further applied in follow-up projects (PT2020).

Since this firm benefited from several QREN I&DT projects (35), the impact on the internal organization had to be evaluated by the set of projects performed during that period. The innovation process in this firm is very structured and the new set of projects are planned yearly, together with an allocated R&D budget, which are selected after a thorough market and strategic analysis of its value for the firm. At this innovation management level, there were no significant changes due to the QREN funded projects. However, due to the high volume of funded I&DT projects the PM stated that: "*there was a need to develop and modify the internal project management practices to handle the complexity of the R&D projects; a new organizational model was adapted and a new formal department for R&D project management was created*", which mainly deals with the project formalities and financial management. This organizational change allowed the project's HR to remain focused on the core R&D activities.

The main output of this project was an innovative technology that is currently being tested with several pilot systems. According to the PM: "*the economic impact of the project is still negligible at the current technology development stage; 1-2 years of pilot demonstration will be required to gather performance data to leverage the technology' international expansion we foresee*". The PM concluded that: "*we expect an impact in the competitiveness of the firm through this project, as this is a novel product that will address a short-term need in the energy sector*".

A summary of the identified incentive additionalities for Firm C is presented in Table 15.

Table 15. FIRM C: SI I&DT project additionalities

Input Additionality		Increased R&D expenditure	
		Project Level	**Firm Level**
Behaviour Additionality	**Strategy**	▪ Expanded highly qualified HR team	▪ Enter new market segment ▪ Future innovation potential
	Operation	▪ Larger scope ▪ Higher risk ▪ Faster development time ▪ Larger scale ▪ Collaboration with PRO	▪ Project management department ▪ Cognitive: new knowledge
Output Additionality		▪ New technology; ▪ Profitability (expected at full scale)	

Source: Matrix adapted from Clarysse *et al.* (2004).

At strategic level, the firm targeted with this project a new market segment it considered very strategic to explore in the future, foreseeing high technological demand and great innovation potential. Aligned with this strategy to move into a new market, the firm expanded their highly-qualified R&D team to reinforce their knowledge and competences in this specific technological area, which stimulated other follow-up projects within the firm. It is noteworthy that potentially these strategic impacts could have been achieved without the incentive, since this project would be carried out with a similar configuration despite de incentive. Therefore, the additionality impact of the incentive at this strategic level may not be so visible. As a firm with large project portfolio, the incentives are used as part of firm's R&D strategy to support projects with higher risk, or more distant from the market. For this reason, at project level, the project additionalities had some impact, since these allowed the firm to develop a larger and more ambitious project, with higher technological risk. Cognitive additionality was observed through the addition of new HR with specific knowledge and collaboration with a subcontracted PRO. The firm already had a large R&D record and innovation management structure, so the impacts at management level were not very significant, but constant learning in these innovation processes is an integral part of their innovation system. Due to a vast portfolio of funded projects, a project management department was created to handle operational matters for all funded projects.

6.2 Discussion

6.2.1 Input Additionality

Based on the projects performed by the selected firms, the input additionality of the awarded subsidy was evaluated. The input additionality evaluates whether the subsidy promotes a higher R&D expenditure by a firm or if it is a replacement for the firms' R&D expenditure (David *et al.*, 2000; Garcia-Quevado, 2004). For both SMEs interviewed, public funding promoted additional R&D spending by the firm on each project, so input additionality was observed. In the case of Firm A this positive effect was more pronounced as without funding the firm would have not done any investment in R&D. In the case of the large firm C, the awarded subsidy substituted part of the pre-allocate R&D budget, so a partial crowding-out effect was observed. As mentioned by the SMEs PM's, they did not have at the time the capacity to financially support the project development and hire dedicated HR. A similar pattern was observed in a study performed on a sample of Spanish firms, where although a general increase in R&D spending was observed as a result of public funding, most of the smaller firms would have not performed the projects without funding and larger firms still would perform the project, with only a slightly increased their R&D investment (Gonzalez *et al.*, 2005). The rational for this observation is that liquidity constrains often affect smaller firms, which do not have easy access to capital or enough years in the market to be able to fund their R&D activities, while larger established firms have more investment capacity and easier access to external investments, due to possessing higher stock of assets and accumulated profits (Cerulli and Poti, 2012). This investment capacity difference is also reflected in the budget of the three selected projects for the case-studies, with the larger firm developing a project with a significantly higher budget.

In the present analysis, the low-tech firm was the one that benefited more from the received incentive as it would have not considered the project otherwise. Public funding can therefore have a high impact on promoting SME's R&D spending by facilitating access to capital to sponsor these activities. A study comparing funding efficiency within low-tech and high-tech firms also suggested that funding is more effective for low-tech firms rather than high-tech, due to inductive effects towards R&D activities (Gonzalez and Pazo, 2008). Although a partial crowding-out effect was observed in the large firm, the incentive still promoted a higher overall R&D investment.

This case-study analysis confirmed the generally accepted argument that without public funding the business R&D investment is sub-optimal (Almus and Czarnitzki, 2003). Public intervention is therefore a necessary instrument to overcome market limitations and reduce the cost of firms' investment in R&D activities, which are mainly directed towards supporting highly-qualified HR (Czarnitzki and Toole, 2007; Guellec and De La Potterie, 2003). In addition, considering the national business sector composition and the recent expansion of business R&D (chapter 3), there is still a reduced group of firms that are collecting profits from innovations, which could be used to fund further R&D. This national structural context contributes for an exacerbated input additionality impact of the incentives, especially for start-up firms or other firms initiating R&D activities.

6.2.2 Behavioural Additionality

With regards to Project Additionality, all firms experienced some additionality with different levels of impact. Overall, the project additionality effect was more pronounced for the SMEs, where the incentive significantly contributed to enhance the scale, scope and acceleration of the project. This additionality was clearly observed in Firm B through the higher complexity of the project activities and higher TRL development, which without funding could have been compromised and hinder the technology development. In the case of the large firm, the scale and acceleration of the project were also increased, however the most prominent dimension was the scope, in the form of the challenge additionality, which resulted from the higher technological risk the firm could take in this project with the incentive. This is one of the main motivations pointed out by the firm to apply for funding. For both high technology intensive firms, the R&D subsidy allowed to minimize the project risk and undertake a more technologically ambitious project. Public funding can have the potential to change the perception of risk by firms, thus positively changing the behaviour towards R&D (Cerulli and Poti, 2012). There is evidence that public incentives can reduce firm uncertainty-derived reluctance to invest in R&D, and that these incentives are actually directed towards the most uncertain projects (Czarnitzki and Toole, 2007). As observed in the case of firm C, large firms developing several R&D projects can strategically use incentive schemes to fund projects with higher technological risk and that are further away the market, and concentrate their funds to develop R&D projects that are less uncertain and close to market. A higher risk may increase the project

innovative potential and market return prospects. This challenge additionality is an important impact of the R&D policy, as it can empower firms to engage in more disruptive forms of innovation, which in turn can generate a greater economic impact and improve international competitivess through the commercialization of high-value technological innovations. In turn, this can positively impact the growth and productivity of the national economy, and bring the country closer to the technological leading economies.

All three firms hired qualified HR for the project development team with the funding support, which remained in the firms after project conclusion. Firm A hired a qualified HR as a project manager that was later allocated to product development, among other tasks, but did not have a significant impact promoting further R&D projects within the Firm. As a low R&D performing firm, this firm depends on the knowledge detained by PRO partners to conduct R&D activities. For both high-tech firms, the new HR were a source of specialized knowledge for the project, and were hired with the ambition to support and further develop the business area of each funded project. In particular for Firm B, the incentive awarded was critical to hire a PhD to develop a new R&D area within the firm that has expanded, which would not have been possible without the funding. These new HR were clearly an integral part of these firms' strategic decisions to be more competitive through technology differentiation in new market areas, as stated by both PMs. This strategic management behaviour can be described by the Dynamic Capabilities theory, where the managers recognize internal resource adaptations that have to be made, such as to redirect internal competences and source new external knowledge, as a response to new market challenges (Teece and Pisano, 1994). The knowledge brought to the firm by these new HR was further developed and applied in subsequent R&D projects, which denotes a long-term strategy for R&D exploitation in that given research area. This knowledge spill-over effect due to hiring highly qualified staff within the firms is a desirable additionality effect of the project incentive, whereby further R&D can be conducted after the funded project conclusion, and the R&D intensity is amplified in the firm.

At organizational level, the development of the funded projects introduced changes on the innovation conduct of the firms. A slight impact was observed for firm A that became more conscious of innovation after this experience and adapted some behaviours to improve their internal product development but without any formality, which is consistent with its low R&D intensity profile. Firm B introduced a more structured and formal character to the innovation process and R&D activities performed by the firm, which had a positive impact towards building innovation management skills and implementing R&D operations. This organizational change enhanced the firm's ability to conduct R&D with permanent effects. Firm C already had an established innovation structure, but created a new department for project management to deal with the bureaucratic work which allowed the project's team to solely focus on R&D activities.

The stock of knowledge of all the firms also benefited through the collaborations established with PRO entities. It is noteworthy that all collaborations identified with PRO in the case-studies evolved from previous interactions between the partners, which also minimises the risk to engaging in new formal collaborations. Due to its low R&D intensity and lack of highly qualified HR, Firm A relied heavily on their PRO partners to acquire new knowledge to support its product development. Furthermore, this firm thrived on tacit and practical knowledge it had accumulated over the years, and the collaboration with PROs brought a more scientific and codified knowledge base they could apply to enhance new services they developed. Both high-technology intensive firms perform in-house R&D and regard these PRO' collaborations as knowledge complements to enhance their knowledge stock in specific areas, and to minimize the scientific risk of the project. This in line with motivations appointed in the literature for cooperation with PRO, which are based on the expectation of accessing new specialized knowledge, improving competences and sharing the risk of the project (Cerulli *et al.*, 2016). The creation of networks to access external knowledge, and the capacity of firms to assimilate and explore it for commercial purposes, is considered critical for firms' innovative capacity (Cohen and Levinthal, 1989). The Absorptive capacity model by Cohen and Levinthal's (1989) postulates that business R&D has a dual role, as it is not only relevant for innovative product or process development, but also to broaden firms' capabilities by absorbing and exploiting external knowledge. This absorbing capacity is also potentiated

by the already existing knowledge in the firm, and the more experienced firms are in R&D the more these will learn from external collaborations, and maximize their R&D potential (Clarysse *et al.*, 2009).

With respect to collaboration between firms in the cases analysed, there was only a significant collaboration established by Firm B. This was a strategic collaboration to financially leverage the technology scale-up to industrial level and to support the firm's market approach, which has been maintained. This example shows how collaborations between firms can positively potentiate R&D results through strategic collaborations, especially in the case of SMEs, which can result in full R&D potential exploitation, productivity gains and market expansion.

One of the main QREN SI I&DT objectives was to promote cooperation and projects between firms and higher education research centres. These case studies have shown that the incentives awarded had also positive contribution promoting collaborations between firms and PROs, which was also observed overall for the SI I&DT instrument (section 5). However, the collaborations between firms were not so significant, which points out that firms are still reluctant to collaborate and engage in these partnerships.

6.2.3 Output additionality

In the case of both high-technology intensity firms, the direct projects' output was still marginal due to the fact that both technologies were not fully validated at full scale, even after more than 3 years of project conclusion. In contrast, firm A launched a new product line within the project timeline and has been enjoying a high return on this project through international expansion. This contrasting result highlights that technology development can require additional development time in order to achieve a tested and validated product up to full scale, ready for market introduction, depending on the technology development stage proposed for the timeframe of the project. On one hand, this full scale validation is a crucial step that has to be taken before market approach, and one that requires additional financial resources, which can delay the final product launch in the market and its internationalization. Firm B overcame this barrier with the strategic partnership created with a larger established firm, but without this support it would struggle to get the financial capacity to back this step. If this full scale-up step is not feasible, the developments made and supported by public funding could be jeopardised. Therefore

innovation policy should predict support until full-development of the new technologies, depending on its complexity, especially for SMEs that by nature have capital constraints. On the other hand, this extra technology development and validation stage beyond the R&D project has also implications on timing for the economic returns of the projects, which will only be observed years after these concluded. For this reason, the overall increase in the national R&D intensity promoted by the SI I&DT, which was demonstrated by an increase in the BERD, can only be fully assessed in the long-term.

Finally, as other studies have observed, not all projects produce visible output additionalities, however this does not mean that other positive impacts of the funding have not occurred in the form of behavioural additionality. As demonstrated by these case studies, behavioural additionalities may contribute to future R&D activities and potentiate follow-up output additionalities, through application of improved innovation management practises and acquired knowledge to follow-up projects (Davenport *et al.*, 1998).

7. Conclusions

The evaluation of the impact of innovation policy instruments is essential to assess both the effectiveness of allocated investments and the returns generated for the national economy. The work developed in this dissertation presented a contribution towards the evaluation of the QREN SI I&DT instrument impacts on beneficiary firms.

The case study analysis has shown that the input additionality of the incentive was considerable in the case of the SMEs, but for the large firm this impact was less pronounced, with partial-crowding out observed. Though in all cases the incentive provided an increased in the firms' R&D expenditure. One of the main SI I&DT objectives was the intensification of the national business R&D efforts, and the case-studies have shown that the incentives awarded had a positive contribution towards meeting this goal, especially for the SMEs. At national level, there was an intensification of the business R&D intensity during the QREN period, with particular relevance in the Norte and Centro regions, which concentrated the highest shares of public incentives for investments in R&D. This increased R&D effort will contribute towards the development of these regions, which are considered less developed and converging regions. However, the overall progress of the national R&D performance is still modest, considering the national R&D intensity goal set at 2.7% of GDP by 2020. As observed in the case-studies, the output of these incentives can be observed in the long-term, therefore the economic impact of the SI I&DT incentives might not be significant at this point in time. Still, this gap in R&D intensity is significant, and these R&D incentives directed at firms have must be complemented with additional measures to improve the overall R&D efforts, if this target is to be achieved. The Portuguese business sector is still very traditional and dominated by small firms, which have typically low or none R&D activity, therefore the endorsement of conditions promoting a more technology based and high-knowledge intensity business sector would be desirable.

The behavioural analysis has shown that project additionality was observed in all case-studies, with the SI I&DT incentive encouraging projects with larger scale, acceleration and scope. For the high-technology intensive firms, the incentive allowed projects with higher technologic risk and uncertainty to be pursued. This challenge additionality

provided by the incentive is an important impact of the R&D policy, as it can empower firms to engage in more disruptive forms of innovation and target for other markets, which in turn can generate a greater economic impact and improve international competitivess through the commercialization of high-value technological innovations. In turn, this can positively impact the growth and productivity of the national economy, and bring the country closer to the technological leading economies.

Collaborations with PRO have a significant cognitive impact on the firms, through the assimilation of new competences and external knowledge that can improve the funded project's innovative potential, and later lead to follow-up projects or services through knowledge spill-over effects, as the case-studies have demonstrated. The promotion of networks with PRO is therefore considered critical for firms' innovative capacity and creation of new economic opportunities. Overall, the SI I&DT effectively promoted collaborations between firms and PRO, although collaborations between firms were not so significant, which shows that firms are still reluctant to engage in strategic partnerships to leverage its R&D performance and improve its competitive strategies. As one case-study demonstrated, strategic collaborations between SMEs and large firms can positively potentiate R&D results, which can result in full R&D potential exploitation, productivity gains and market share expansion.

Most of the incentives awarded to the firms were applied to hire highly qualified staff, which in the case of the high-technology firms were also a source of new competences and knowledge for the firm that can be capitalized in further R&D activities. For the high-technology intensive firms studied, the new HR were also a relevant piece of these firms' competitive strategy to explore new market areas and compete through technology differentiation. Two of the main QREN SI I&DT objectives were to improve firms' competitiveness through new knowledge creation and stimulate the assimilation of new knowledge capable of inducing new economic opportunities. The case studies have demonstrated that the incentive allowed the firms to hire highly qualified HR and develop new knowledge that was applied to develop further R&D projects or associated services. At organization level, the incentive had impact in one of the SMEs by improving innovation management skills and standardising innovation processes. This is a

permanent behavioural impact within the firm that can enhance its ability to perform in-house R&D and to implement more effective innovation processes. In the case-study of the large firm, the organizational impacts were not so significant at innovation management level, since these practices were already established, but a support unit was implemented to manage funding operational bureaucracies.

The output additionality of the incentives may not be immediately observed, especially for projects concerning technology development, due to scale-up development stages and validation in real operating conditions, as case studies have evidenced. These additional steps before full commercialisation introduce delays in the expected firms' investment returns, and the overall incentive scheme' economic impact. For this reason, the overall increase in the national R&D intensity promoted by the SI I&DT, which was demonstrated by an increase in the BERD, can only be fully assessed in the long-term. In addition, the QREN SI I&DT is considered to be the first R&D funding programme designed to fund national business R&D, which had an unprecedented volume of incentives awarded to a wide range of beneficiary firms. Therefore, the expansion of the national business R&D is still recent and the associated innovation management processes are still improving at firm level, so the results of the national business R&D incentive policy are expected to accompany this evolving progress in the following years.

Despite the lack of output additionality, the case-study analysis highlighted the existence of incentives' behavioural impacts within the firms that can potentiate future R&D activities and generate other output additionalities, through knowledge application, collaborations established and improved innovation management skills. This observation demonstrates that the SI I&DT instrument was effective to promote a wide scope of additionalities that generated positive impacts at different levels within the studied firms. This dissertation provided a valuable insight and contribution into the characterization of behavioural additionality impacts of R&D incentives in the Portuguese context, which is still unexplored. Short-term policy evaluations should therefore integrate behaviour additionality assessment to provide a more thorough and comprehensive evaluation of public R&D funding, which can be valuable towards policy improvement and a more efficient allocation of funds.

Finally, the case-study analysis performed was limited to three firms and consequently the behavioural effects were not extensively analysed within the SI I&DT group of funded firms. Also, the conclusions from the case-study analysis performed in this dissertation cannot be fully generalised to the whole SI I&DT funding instrument, as these represent the specific experiences of only 3 firms. It would be therefore interesting to expand this study in future research and explore the behavioural additionality across a wider sample of firms.

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9. Appendix

Semi-structured interview script developed for this dissertation.

I. Firm Characterization

Firm data:

Name	
Year of constitution	
Dimension of work force	
Sector of activity	

Interviewee:

Name	
Position	
Relation to the project	

II. SI I&DT project characterization

Number of SI I&DT projects the firm benefited:

Individual	
Collaborative – project leader	
Collaborative - promotor	

Selected SI I&DT project characterization:

Project	
Objective	
Technological Domain	
Partners	
Execution	
Total Budget	
Funding body	

III. Pre-project characterization

- Can you describe the firm's context at the time this project idea was discussed and put forward?
- What were the main strategic motivations for developing this project?
- Without funding, would the firm still develop this project? Under which conditions?

No	
Yes, without changes, resorting to own funding	
Yes, without changes, resorting external funding	
Yes, but with budget reduction	
Yes, but with project changes (scale, scope, development time, etc)	
Yes, with other changes. Which?	

- How was the R&D intensity level and experience, and innovation processes organized within the firm before the project?

Did you perform In-house R&D?
Were R&D activities formally planned and had set budgets?
Did you had a formal innovation unit or research facilities?
Did you had R&D expenditure?
Did the firm had HR dedicated to R&D or with responsibilities at innovation management?
Did you hold collaborations with PROs?
Did you had collaborations with other firms for R&D purposes?
Did you launch innovative products/services?

IV. Project development impact

- What was the impact on the R&D intensity of the firm?
- What was the impact on the innovation management and internal organization of the firm?
- What was the impact on internal competences, knowledge base, and HR dedicated to R&D?
- What was the impact at collaboration level?
- What were the economic or strategic impacts of the project?
- What were the project outputs?

V. Overall funding experience

- What were the most significant impacts the funded project had on the firm?
- Has the firm's attitude towards innovation and R&D change with this project?
- What were the negative aspects of this funding instrument?